# RESEARCH IN ADVANCED CONCEPTS IN BIOTECHNOLOGY, HUMAN ANALOGS AND BIONICS

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#### ABSTRACT

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This report describes the human analog of the visual sensor. Analysis of the operation of the human eye was conducted utilizing the framework of the Man-Machine Methodology. In order to provide a familiarity with the terms used in the analysis, an outline of the physiology and anatomy of the eye is presented. Also an outline of the photoreceptor processes is given.

It was found that the human analog provided a penetrating insight into the fundamental mechanisms and processes carried out in the eye. Where gaps in the assembled data were located, basic research projects were suggested. Machine extenders could be directly developed from the human analog. Further scientific investigations in the format of the human analog may be expected to produce a deeper understanding of the fundamental operation of the human body.

Information presented in this report can be directly applied to the design of visual machine extenders that operate on the same principles as the human eye. One advantage that such a bionic device would have is that it could operate over a narrow frequency range after detecting impinging radiation. New and efficient devices that function in the visible, infra-red, ultra-violet or, in fact, in any portion of the electromagnetic spectrum could be build that utilize the fundamental ideas presented in this report on the human analog of the eye.

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#### INTRODUCTION

This is the first quarterly report for NASA Contract NASw-780, Research in Advanced Concepts in Biotechnology, Human Analogs and Bionics, covering the period from 8 July 1963 to 8 October 1963. In this report, Teledyne Systems Corporation has concentrated on Task One-a and Task Two-1 of the contract.

The objectives of the effort which is described in this report are the following:

# Task One

Conduct advanced research in the field of Human Analogs. This will include analyses to define selected basic human body systems in terms of mathematical models compatible with computer techniques so as to establish the fundamental interface relationships between Man and Machine for Advanced Space Applications. Systems Analysis Methodology which was developed for the Director of Biotechnology and Human Research under NASA Contract NASw-567 will be used in conducting the proposed advanced research in Human Analogs. Mathematical models will be established for the matrices pertinent to the selected human body systems, and for the related machine functions.

The manipulation of the Man and Machine models in the Systems Analysis matrices will establish:

a. The Human Analogs for the selected human body systems.

#### Task II-1

This task shall be conducted as follows:

 Examine the selected physiological functions to establish the fundamental mechanisms and processes. Reseach in Advanced Concepts in Biotechnology, Human Analogs and Bionics began with a review of the literature concerned with the physiology of man. The human body was studied with emphasis on those subsystems that handle information. Study was directed toward examining how man inputs, distributes and controls and outputs information. These three categories were used to classify the subsystems of man. This breakdown is shown in Table I.

Input	Distribution and Control	Output
Visual	Nervous	Musculo-Skeletal
Auditory	Endocrine	(Movement and speech)
Gustatory	Small Intestine (Digestion)	Skin (Sweat, flakes and Thermal)
Olfactory		
Tactile	Cardiovascular	Excretory
Radiation		Reproductive
Respiration		
Upper G. I. Tract (Entering food for digestion)		

Subsystems of Man Table I.

From Table I, one subsystem from each category was selected to be analyzed. The visual, nervous and musculo-skeletal subystems were chosen. The major criteria used in selection was that each represented the subsystem of greatest apparent information flow when examining input, distribution and and control, and output respectively. These three categories are basic to the Man-Machine Systems Methodlogy. The Methodology is summarized in Appendix A.

The visual sensor, which is an information input subsystem, is the subject of this report. An analysis of the operation of the human eye will be conducted for a number of reasons. First, the analysis will produce the Human Analog of the visual sensor. In assembling the data within the framework of the Man-Machine Systems Methodology, areas where physiological investigation is lacking will be found. Finally, the analysis will be used as the basis upon which to determine extensions of the visual sensor.

#### **HUMAN ANALOGS**

It is quite important that the meaning of a Human Analog be established for purposes of this report and also to distinguish between it and a Machine Analog. It is perhaps most easily done by using an illustration from a field that has made use of analogs for the purpose of study. Such a field is found in the realm of mechanics. Springs, masses and vibratory systems are for the most part describable by sets of differential equations. These equations constitute a symbolic representation of the mechanical system which they describe. Quantities vary in the equations in a manner which is analogous to the positions and velocities of different parts of the mechanical system; thus, the proper set of differential equations are said to be a mathematical analog of the mechanical system.

It is possible to consider other systems that can be symbolized in an identical mathematical form. For example, electrical circuit components give rise to mathematical models that are similar in form to the mechanical systems. It is this fact that allows a collection of particular circuit elements (i.e., an analog computer) to perform in a functional fashion that is identical to the mechanical system. Currents and voltages are seen to be analogous to positions and velocities. Once the analogous properties have been established, it becomes a simple matter to combine elements from analogous systems. Thus, a guided missile, which is basically a mechanical structure, utilizes electrical amplifiers and filters to control its kinematic behavior.

The human analog is the symbolic representation of a human biological function. It has already been established in the newly developing field of bionics that as human analogs become established, improved machine analogs (extenders) can be specified. Just as in the case of the guided missile, a combination of analogous systems is utilized. It should also be possible to relate man and his machine extenders so that they operate in a perfect union of analogous systems. The cardiac pacer is one excellent example of what this union can mean to man even in rudementary form.

The first step then is to establish a symbolic analog or human analog. Unfortunately there are no sets of differential equations that describe the functioning of man's interrelated systems as apply to the field of mechanics. On the other hand, equations are merely a convenient way of relating variables. This data can also be viewed in a tabular form, and, in fact, most highly non linear problems are approached in precisely this manner. Relationships are established and are analyzed by digital data processing equipments. These equipments in turn allow the investigator to predict the behavior of the system under variable input conditions. Problems of tabulation and retrieval of information have been dealt with by Teledyne Systems Corporation under Contract NASw-567. The Methodology developed under this contract provides the basis for the establishment of the human analog.

Teledyne Systems Corporation chose the human analog of man's visual sensor as its first application of the Methodology. Information had to be extracted from the literature and set up in the symbolic format of the Methodology. When the literature lacked necessary information, a hypothesis was formed to act as a bridge between existing areas of knowledge concerning the basic principles by which the eye operates.

It was found in the course of assembling this information that many physiological and physical principles were revealed to apply to the operation of the eye, i.e., cellular division of work, field partical-interaction, photochemistry, etc. Thus, to fully understand the eye and its operation requires a full understanding of exactly what goes on in any photochemical reaction.

A final question should be raised before going to the specific subject material of this report, that is, of what benefit to NASA is the establishment of human analogs and machine analogs?

Human analog studies are necessary to the successful execution of any space mission from the following standpoints:

- 1. Prediction of survival of the human engaged in performing a space mission depends upon formulating human responses to hostile environments. The human analog is a predictive model.
- 2. In environmental simulation studies, parameters to be measured must be specified based upon their value in predicting consequences of temporary extremes. The human analog establishes the essential parameters.
- 3. To extend man's capabilities it is essential that the manner in which he functions is understood so that instruments, machines and vehicles can be designed that will efficiently enhance and extend man's known faculties. Human analogs indicate the requirements for machine analogs.

#### SUMMARY OF FINDINGS

Scientific investigation following the format of the Man-Machine Methodology to establish the human analog of the eye was found to be an excellent method to explain the fundamental mechanisms and processes carried out in the visual sensor. Many advantages were realized by developing the human analog. Information contained in the analog can be understood by workers in all branches of research since the Methodology terminology has application to every field of science. Areas where basic research could produce major new concepts into the visual process were found. Studies of how the eye detects visible radiation and how the visual sensor operates to determine color were found to be two of these areas. Tracing the information signal through the eye was an effective way to uncover the visual processes. Focusing on the flow of the information signal was suggested as a guide to scientific investigations that are studying functional operation. The human analog can be directly applied to the design of machine extenders to aid the eye. There are many areas of scientific endeavor that can benefit from the research that has been conducted to establish the visual human analog.

SUBSYSTEM LEVEL EXAMINATION OF THE OPERATION OF THE HUMAN EYE

# OUTLINE OF THE PHYSIOLOGY AND ANATOMY OF THE EYE

Before beginning to apply the Methodology, a review of the physiology of the eye was made. The purpose of this study was to gather the facts that would be assembled according to the framework of the Methodology.

In performing an examination of the physiology of the eye it is necessary to describe the boundaries of this subsystem. Five-sixths of the eye is bounded by the sclera, which is white and opaque. From the front of the eye, a portion of the sclera may be seen as the white of the eye. The sclera is composed of a tough inelastic fibrous material that forms the protective exterior coat of the eye. This coat maintains the shape of the eye and gives it an almost spherical form. An average eye can be contained within a one-inch sphere. The remaining one-sixth sphere not covered by the sclera is protected by the cornea.

Anteriorly (toward the front of the skull) the eye is bounded by the cornea. This coating is made of material that is very similar to that found in the sclera, but in the cornea the fibers are transparent to a specific band of electromagnetic radiation (203 m $\mu$  to at least 3000 m $\mu$ ,  $^1$  1 m $\mu$  =  $^{-9}$  meter). Thus the cornea acts as a frequency filter.

The cornea is also one of the components in the eye that refracts light and thus brings it to focus on the retina. The normal eye has a focusing power of 60 diopters. A diopter is the reciprocal of the focal length in meters. Focusing power is directly proportional to the differential in refractive indices between media. Air has a refractive index of 1.000

while the entire eye can be considered to have an index of 1.33 which is the same index as water. Comparatively there is a large differential in refractive index between air (1.000) and the cornea (1.376). This large difference means that the air-cornea interface has the greatest refractive power found in the eye. In fact, the cornea contributes about 40 diopters of the total power of the eye. <sup>2</sup>

Less bending of light takes place at the cornea-aqueous humor interface since the refractive index differential is small (1.376 for cornea and 1.336 for aqueous humor). The aqueous is 99% water containing dissolved salts. Composition of this fluid is quite similar in most respects to blood plasma and to the virteous humor. Sometimes the entire aqueous humor is called the anterior chamber (as opposed to vitreous body which is posterior), but this name can be confusing since the liquid is anatomically separated into two areas that are called the posterior and anterior chambers. These chambers are divided by the iris.

Physiologically the iris controls the amount of light entering the eye. Control is conducted by regulating the diameter of the pupil. The muscle that regulates this diameter is directed by information received in the retina since there are no light receptors in the iris.

Immediately posterior to the pupil of the iris is the lens (refractive index 1.4). The function of the lens is to focus entering light on the retina. As in the iris, the lens has no light receptors that can detect the focus of

light on the retina. Thus the signals to control the muscles of the lens must originate from the retina. These muscles change the curvature of the lens and therefore influence the refraction of light rays.

Light that leaves the lens is transmitted through the vitreous body. This body contains a transparent gel that is called the vitreous humor and is similar to raw egg white. Chemically the vitreous and aqueous are similar. Both have approximately the refractive index of water and both apply pressure to their surroundings.

In the posterior direction, the vitreous humor exerts pressure on the retina. The retina may best be viewed as a location for many components of the eye and not as a functional unit. This lining is not completely transparent because light must traverse the 0.1 mm thickness of the retina to be absorbed in the posterior surface. Light that is not taken in by the retina strikes the choroid.

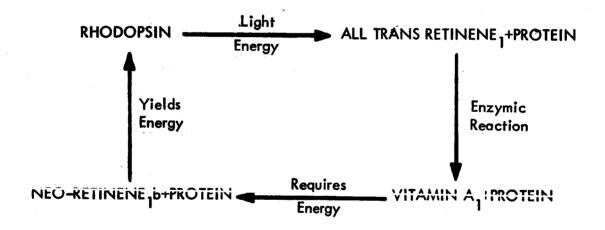
Functionally the choroid acts to absorb all incident rays so that no reflected light is allowed to stimulate the receptors. For this purpose, the choroid is black. The choroid lines the entire posterior half of the eye except where pierced by the optic nerve. This lining is in contact with the sclera in the posterior direction while anteriorly contact is made with the pigment epithelium layer of the retina.

Many dome-shaped cells compose the pigment epithelium. Near the cell boundaries a pigment called fuscin is concentrated. This pigment has an absorption band from 397 to 723 m $\mu$  which covers the visible range. Throughout this range, the fuscin absorbs photons and transfers energy to

the photochemical substances in the light receptors that are in contact with the pigment epithelium. The two types of receptors in the eye are called rods and cones because of their respective shapes. Rods contain a photochemical called rhodopsin.

Rhodopsin is a very complex organic compound that has an atomic weight that is quoted as being from  $46,000^6$  to  $270,000^7$ . The two basic components of rhodopsin are retinene, and scotopsin (protein).

Initially the rhodopsin is dissociated into all-trans-retinene and portein. (See Table 2).



RHODOPSIN CYCLE TABLE 2

**TSC 3345** 

The all-trans-retinene  $_{l}$  is further reduced to vitamin  $A_{l}$ . Energy is required to convert the vitamin  $A_{l}$  to neo-retinene  $_{l}$  b, but the recombination to form rhodopsin is spontaneous and yields energy. A short exposure of rhodopsin to instense light produces considerably more all-trans-retinene  $_{l}$  than vitamin  $A_{l}$ ; during a long exposure to weak light, more

all-trans-retinene  $_{l}$  is converted to vitamin  $A_{l}$  shifting the equilibrium so that more vitamin  $A_{l}$  is present.

Sometimes rhodopsin is called visual purple. When it is broken down, the color changes from purple to white. This bleaching is accompanied by a major deformation in the configuration of the protein scotopsin. As recombination of the protein and retinene takes place, the original configuration of the protein must be restored. It is not clear if the retinene protein recombination or the readjustment in the configuration of the protein accounts for the excitation that rhodopsin produces.

This explanation of the breakdown and resynthesis of rhodopsin deviates from the classical approach, but Table 2 indicates the hypothetical cycle derived from present research.

The photochemical rhodopsin is located in the rods and is broken down even in dim lights and thus makes night vision possible. Rods have another characteristic that makes them especially adept for seeing in little light. This characteristic is that frequently the effect of many rods are summed to stimulate one centripetal bipolar cell. Centripetal cells are sometimes referred to as the primary neurons, since they are the first cells to be stimulated by the receptors. See Figure 1.

Though rods give excellent night vision, in bright light all the rhodopsin breaks down simultaneously, and the receptors become ineffectual. Now the cones, which are the other type of light receptor, begin operating. Cones contain the photochemical iodopsin and are found throughout the retina. In the central portion of the retina, which is the

m CHOROID

i CENTRIFUGAL BIPOLAR CELL

f AMACRINE CELL

c ROD

(SOURCE: J.D.SPOONER, OCULAR ANATOMY, p. 45-1957)

FIGURE 1

fovea (1500 m $\mu$  in diameter)<sup>9</sup>, the cones are the only receptors. Generally one cone stimulates only one centripetal bipolar cell and thus gives more detailed and distinct vision than the rods because spacial integrity is maintained.

Centripetal bipolar cells stimulate the secondary neurons called ganglion cells. The axons of the ganglion cells comprise the optic nerve. Interconnections between receptors, centripetal bipolar cells and ganglion cells are made by association cells.

Association cells include the following: amacrine, centrifugal bipolar, horizontal and centrifugal fibers. Amacrine cells are in reversed position with respect to the rest of the retina since they face the ganglion cells. An association between ganglion cells and possibly the centripetal bipolar cells is provided by the amacrine cells. This association may be in either direction because amacrine cells are not bipolar and have no axons. <sup>10</sup> See Figure 1.

An association cell that has both axons and dendrites is the centrifugal bipolar cell which is closely related to the amacrine cell. Centrifugal cells receive impulses from centripetal bipolar cells, ganglion cells, and centrifugal fibers and transmit them to the receptors. Centrifugal fibers are derived via the optic nerve from the brain. It is possible that the brain sends inhibtion and facilitation information to the neurons in the retina by means of the centrifugal fibers. Another type of association cell present in the retina is the horizontal cell that electrically ties the rods and cones together. Horizontal cells transmit electric pulses to receptors that are as far as 1 mm away. This distribution of pulses gives spacial induction. 11

Beside association cells, there are neurogolical cells in the retina. The major neurological cell is the Muller fiber that electrically insulates the neurons and holds them a controlled distance apart.

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SUBSYSTEM LEVEL APPLICATION OF THE MAN-MACHINE SYSTEMS METHODOLOGY TO ANALYZE THE OPERATION OF THE HUMAN EYE

# ANALYSIS OF THE OPERATION OF THE HUMAN EYE

Prior to examining the analysis of the Operation of the Human Eye, it is strongly suggested that the reader, who is not familiar with the Man-Machine Systems Methodology, refer to the appendix where the overall procedure is explained.

In the analysis that follows, a number of files are presented that individually refer to a specific intersection on the Subsystem Matrix Charts (pages 25 and 34). Data is recorded on Environment, Function, Configuration and Material Information Sheets as well as on drawings. Preceding each file is a discussion of the steps taken to fillout the Information Sheets. Next is a Subsystem Matrix Chart that has the intersection under consideration blacked in. Intersections that have been previously examined are outlined. Following the chart are the Information Sheets themselves with the attendant drawings.

## Guide to Information Sheets

On beginning to apply the Methodology to the analysis of the operation of the human eye, the matrix charts were scanned to find the level that contained the visual sensor as an element. From the missions level, which is the most general, this scanning continued until the subsystem level matrix level chart was encountered. The Subsystem Matrix Charts are on pages 25 and 34. The subsystem level chart lists the eye under the column man, input, sensory, visual. In tracing this column down, all the influencing factors were encountered.

The first influencing factor that must be considered is environment. For the eye, the environment factor chosen for initial consideration was radiation, electromagnetic, visible. This is the intersection 4(subsystem level), 05(visible aspect), 01(man, input, sensory, visual column). For this intersection, a file was prepared that contained all the applicable information sheets. (Environment, Function, Configuration, and Materials).

On the Environment Information sheet, page 26, the parameters that were required to define radiation in the visible spectrum were stated. These parameters are frequency and intensity. It was felt that no meaningful entry could be made under the heading "amount of normal frequency" because visible light is rather uniformly distributed over the spectrum; consequently, the minimum and maximum frequencies define the range of visible light. For the parameter of intensity, the normal, minimum and maximum frequencies were found and listed on this information sheet.

Next, the supplementary information sheet of function, page 27 was filled out. The Methodology required that the entries on this sheet at the subsystem level be made with respect to the entire eye omitting reference to any of its components. The first column on this sheet asked for a statement of the functional aspect of the entire eye. To find this statement, the general aspects of function on the subsystem level matrix chart were scanned. Since the eye is a sensory subsystem that brings information to the nervous subsystem, the general aspect of input data was chosen to fill the first column.

In the second column, the object that directs visible radiation to the eye must be stated. The form of the energy that strikes the eye is a spacial relationship of light. This spacial relationship emanates from the object which is a visible image.

The following three columns on the function information sheet are labeled parameter, property and characteristic. These columns, that describe the object, supply unwanted details in the explanation of the general function of the entire eye at the subsystem level, and these spaces are blank.

Under the "convert to" column, a statement was made about what the output portion of the eye - the optic nerve - transmits to the nerves subsystem. This column contains the information that electric pulses are transmitted to the nervous subsystem. The next column asked for the method of conversion. Here the question first arises as to how the conversion from visible light to electric pulses takes place. This question cannot be answered at the subsystem level because a discussion of chemical

and atomic interactions is required. Thus only the general statement that light energy undergoes a conversion was made. A detailed analysis of the conversion will begin on the component level where chemical interactions can be discussed. The mechanism of conversion could not be stated at the subsystem level, but the operation was given. In observing the entire eye, the operation was seen to be the absorption of light energy.

The second supplementary sheet that was needed to describe the environment was the configuration form, page 28. In the first column of this form, there is space for the aspect. The subsystem level matrix chart lists the aspects of configuration. First the parts aspect was investigated in its relation to that portion of the human eye that was affected by visible radiation. For this aspect, each of the columns on the configuration information sheet was noted, and drawings were made to illustrate those areas that were pertinent to the environment influencing factor.

Under the column "Connection of Parts", the drawing called Components of the Eye in Visible Radiation Path, page 29, was called out. This drawing points out those parts of the eye that are affected by visible radiation. A portion of the retina is drawn in an inset. The inset shows those components that light impinges upon.

The column labeled "Environment Interface In" calls out drawing number 4-05-01-2. On this drawing there is a transverse section of the visual sensor. The boundary between the atmosphere and the eye is the outer membranous coating over the cornea. This is a liquid like layer that continuously cleanses the cornea. At this boundary, the eye first interacts with the visible radiation.

After the eye modifies the visible radiation, the information signal is transmitted to the nervous subsystem. The transmission takes place across the "Environment Interface Out", which is the next column on the configuration information sheet. Drawing 4-05-01-3 shows the interface out which is bounded by the optic nerve and the lateral geniculate bodies. These are the first neurons in the nervous subsystem to receive electric pulses from the eye. Each optic nerve fiber is related to five or six lateral geniculate neuron cells.

On this drawing, it will be noted that light must pass through a considerable portion of the retina before striking the photoreceptors (rods and cones). The light is filtered as it passes through the components of the retina. A question of function is posed by the configuration of the retina. Usually there is a reason for a specific placement of parts in nature. What is the purpose of the inverted retina? This question will be answered in the course of the analysis of the eye.

At this point, the next aspect of configuration was located on the subsystem matrix chart. The aspect is called support structure. For the eye the support structure is composed of the external muscles. Since there is no direct interaction of the support structure and the environment (visible radiation), this aspect was not considered further on the configuration information sheet. A similar situation exists for the configurational aspects called container, internal dynamics and external dynamics.

The final form encountered under the environment influencing factor was the Material Information sheet, page 32. On this sheet, a list of the components of the eye that are affected by visible radiation is required. The list was composed and included all of the parts that were illustrated on the drawing "Components of the Eye in Visible Radiation Path".

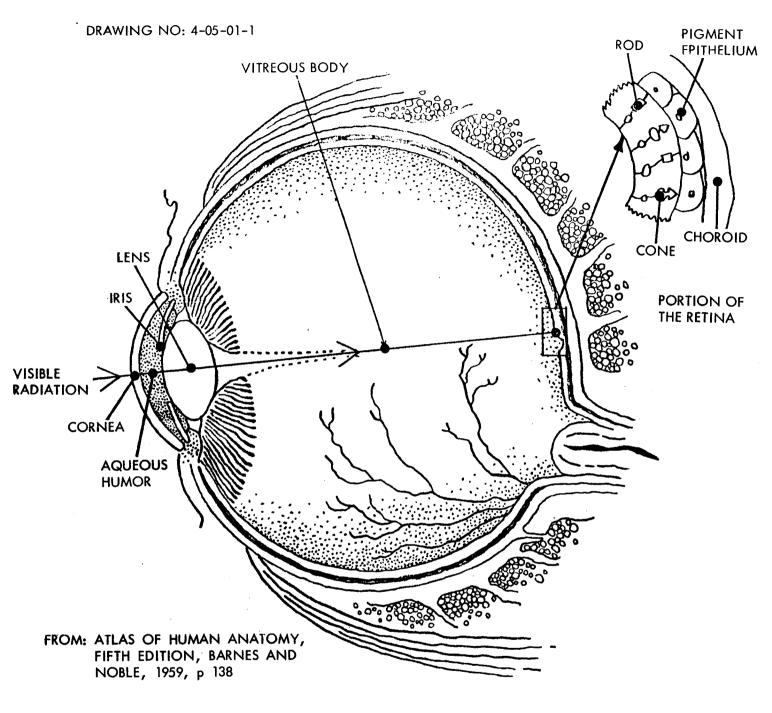
Four columns on the material information sheet are labeled: existence, availability, producibility and relative cost. These four terms relate to the synthesis of materials so they may be used in design. In the present case, an analysis of an existing subsystem (the eye) is being made, and thus consideration of these terms is not necessary.

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		CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED	
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		OPERATION	absorption of light energy
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NOI	,	METHOD SUB-DETAIL NO.2	
CTION INFORMATION		METHOD SUB-DETAIL NO.1	
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CTION	, Visual	CONVERT TO	elec- tric pulses
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	Man, Input,	PROPERTY	
	1 1	PARA- METER	
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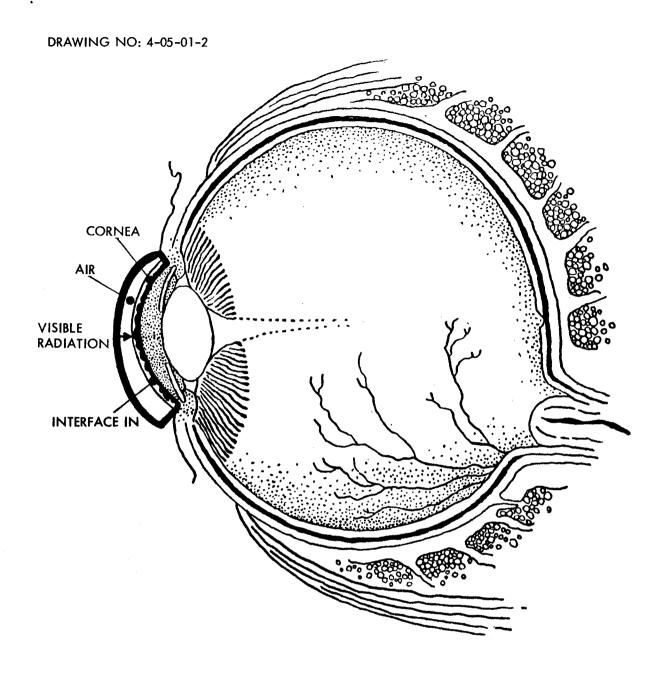
TSC1642

CONFIGURATION INFORMATION		MOTION OF INTERFACE INTERFACE LIMITS ARE EXCEEDED	air - optic	+	Drawing lateral	7	4-05-01-2 bodies	Drawing	No.	4-05-01-3								
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COMPONENTS OF THE EYE IN VISIBLE RADIATION PATH TRANSVERSE SECTION OF EYE ENVIRONMENT INFLUENCING FACTOR

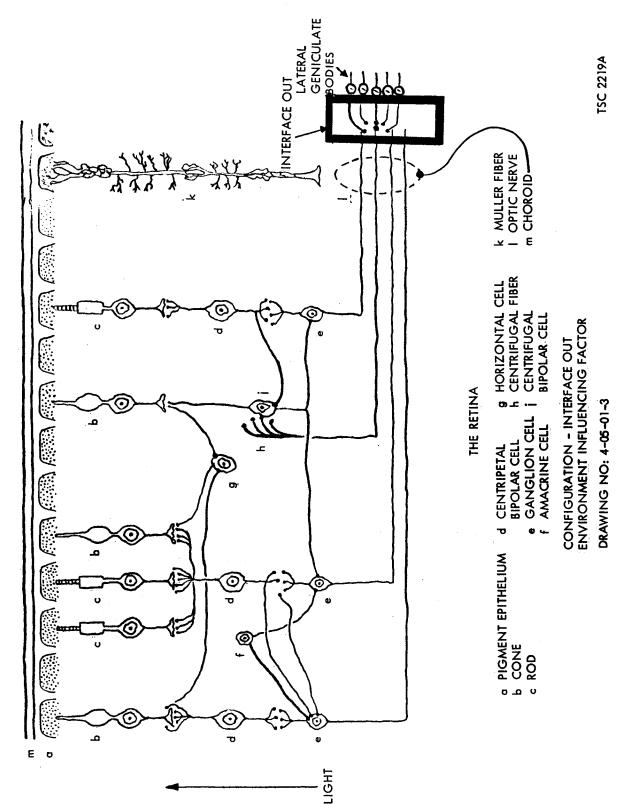
DRAWING NO: 4-05-01-1



CONFIGURATION - INTERFACE IN TRANSVERSE SECTION OF EYE ENVIRONMENT INFLUENCING FACTOR

DRAWING NO: 4-05-01-2

TSC 2218B



		<	MATERIAL INFORMATION	INFOR	MATION
FILE NO: 4-05-01	ELEMENT:	Man, Input	Input, Sensory, Visual	Visual	
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cornea					
aqueous humor	,				
iris					
lens					
vitreous body					
choroid					
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File No: 4-78-01

# Guide to System Design Sheet

The first intersection that was encountered on the subsystem level matrix chart (shown on following page) under the function influencing factor was identified as 4-78-01. This intersection provided for a general functional breakdown of the entire eye into the segments of input, distribution and control, and output. A System Design sheet was used to present the "Major Components of the Eye".

There are two interfaces on the System Design sheet that require an explanation. The first is between the input and the distribution and control portions of the eye. It was hypothesized that electrons are transmitted between the rod and cone surface and the rod and cone proper. Between the distribution and control and the output portions, experimental evidence has verified that there is transverse ion flow.

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File No. 4-78-01

File No: 4-79-01

On the sample subsystem level matrix chart, page 34, the "78" is circled and the intersection 4-79-01 is blacked in. The outlined numeral indicates that intersection 78 has been previously considered, and the darkened square shows the intersection that is presently being investigated. Thus attention is drawn to the functional aspect of input, data, detect.

In the first column of the function information sheet, the aspect was recorded as detect. This aspect is a description of how the eye initially becomes aware that a visible image is directing radiation toward the visual sensor. The object asked for in the second column is the visible image which sends visible radiation to the eye. Visible radiation is the parameter of the object. Following parameter, the next column lists the properties of the visible radiation. These properties are frequency and intensity. The characteristic of frequency is given as periodicity.

Next, the "Convert To" column provides space to state the modified energy form of the object after detection has taken place. To fill in this column, an understanding must be obtained of what occurs in the eye when detection of visible radiation takes place. A search of the literature yielded no explanation of the detection function, and thus a hypothesis was made.

The hypothesis was developed by attempting to explain the interaction between visible radiation and materials of the eye that are affected by light. This hypothesis was formulated by explaining interactions between electromagnetic waves and atoms. A discussion of this type

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involves basic physics relationships, and thus the details of the hypothesis will be presented at a lower level of the Methodology. It is not necessary to become involved in these details at the subsystem level. All that need be said here is that the hypothesis is based on the phenomenon of resonance, and leads to the statement that radiation detection takes place by means of resonance.

When the resonance hypothesis is extended to the eye, structures can be found in the surface of the receptors that have a latent ability to resonante. This latent ability is utilized, and resonance is excited by the visible radiation that is striking the surface of the receptors.

Now the "Convert To" column could be filled out. The visible image transmits energy to the eye that is absorbed by resonance in some structure within the eye. Under "Method" the statement is made that there is an interaction of the electromagnetic field with the resonant structure and the method sub-detail no. 1 is concerned with the fact that forces are exerted on the resonant structure.

At the subsystem level, the mechanism could not be described, but the operation was stated. To explain the operation, it was noted that detection begins when visible radiation strikes the cornea and continues as transmission takes place through the eye. Finally the visible radiation penetrates the surface of the receptors (rods and cones); here absorption occurs - resonance takes place - and an energy conversion is brought about. The function of detection is completed by this initial energy conversion.

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The Configuration Information sheet was next filled out. Only the Configurational aspect concerned with parts was considered because this is the one aspect that is involved in detection. Drawings were made to illustrate the process of detection as well as to show the anatomical parts of the eye concerned with this aspect.

A function schematic was drawn, Drawing 4-79-01-1. At the top of this drawing, the three steps in detection are shown, while the remainder of the illustration depicts those parts of the eye that carry out the process. Acceptance of visible radiation is shown to take place at the cornea and the transmission of the radiation is through the aqueous humor, lens and vitreous body. Finally resonance is excited in the receptor (rod and cone) surface. The cross sectional view of the receptors indicates that the surface, not the receptor proper, contains the resonant structure.

On Drawing 4-79-01-2, the Interface In is shown. This is the interface where the aspect of detection begins. The drawing indicates that the portion of the cornea that is exposed to the air is the Interface In.

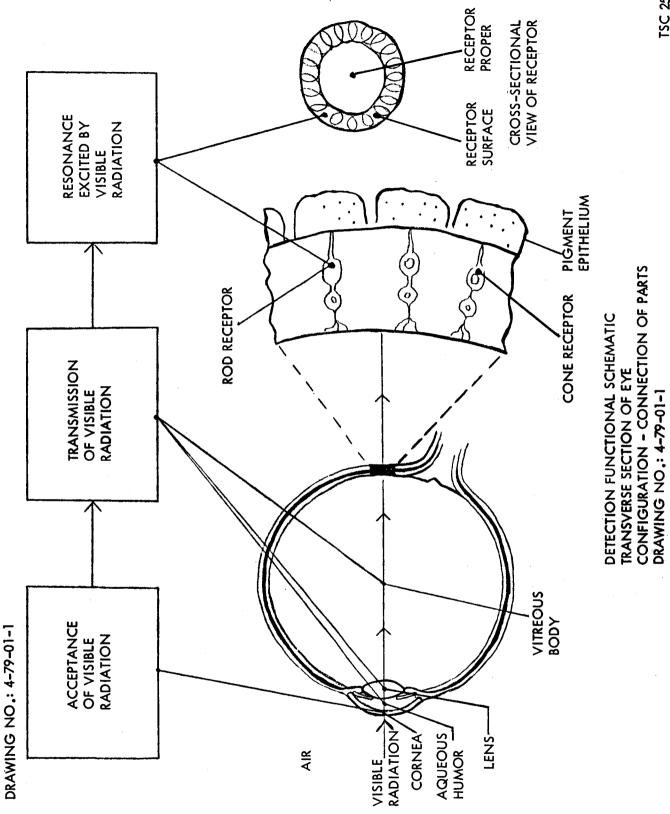
The next drawing shows the Interface Out. This is Drawing 4-79-01-3. On this sheet a cross sectional view of a receptor is shown. The illustration indicates that the detection function is completed at the border of the receptor surface and receptor proper.

Listed on the Material Information sheet are those components of the eye that are involved in the detection of visible radiation.

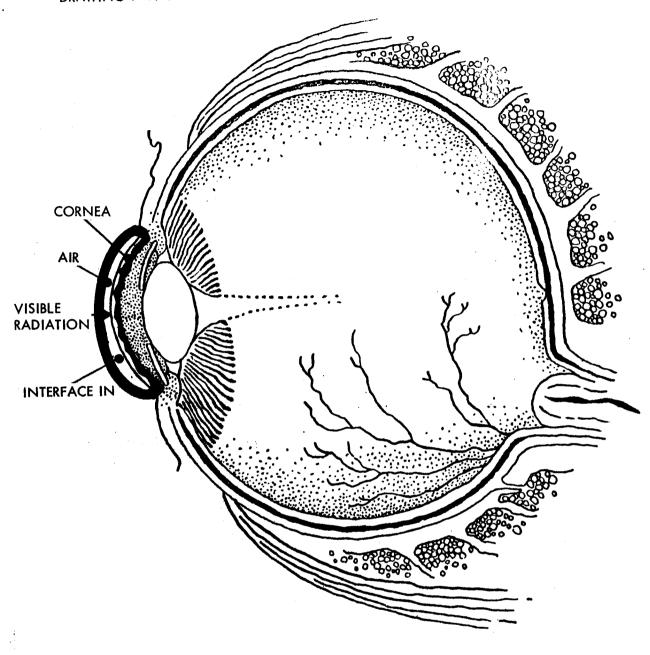
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		CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED	
		OPERATION SUB-DETAIL NO. 2	
		OPERATION OPERATION SUB-DETAIL NO. 1 NO. 2	
		OPERATION	trans- missior absorp- tion of visible radia- tion
		MECH- ANISM	
NOI		METHOD SUB-DETAIL NO.2	
CTION INFORMATION	٦	METHOD SUB-DETAIL NO.1	force on a struc- ture
INFO	, VISUAL	МЕТНОВ	inter- action of electro mag- netic field with reson- ant struc- ture
CTION	SENSORY,	CONVERT	reson- inter- ance action in a of struc- electr ture mag- netic field with reson ant struc- ture
FUN		CHARACT- ERISTIC	period- icity and ampli- tude
	MAN, INPUT,	PROPERTY	freq- uency and inten- sity
		PARA- METER	visible freq- radia- uency tion and inten- sity
	ELEMENT:	овлест	visible image
	FILE NO: 4-79-01	DEFINITION	ASPECT: Detect

			CONFIG	CONFIGURATION INFORMATION	INFOR	MATION			
FILE NO: 4-79-01	ELEMENT:	Man, Input,	t, Sensory,	Visual		v.			
DRAWINGS	ARRANGEMENT	CONNECTION				DEGREES	ENVIRONMENT	ENVIRONMENT	CHANGE WHEN
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DRAWING NO: 4-79-01-2

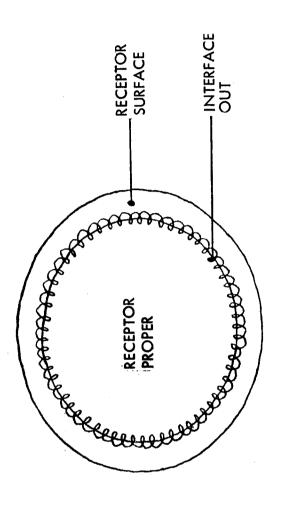


CONFIGURATION - INTERFACE IN TRANSVERSE SECTION OF EYE DETECTION FUNCTION ASPECT

DRAWING NO: 4-79-01-2

TSC 2218C

DRAWING NO.: 4-79-01-3



CONFIGURATION - INTERFACE OUT CROSS SECTION OF RECEPTOR DETECTION FUNCTIONAL ASPECT DRAWING NO.: 4-79-01-3

		*	MATERIAL	INFORMATION	ATION
FILE NO:	ELEMENT:	Man, Inp	Input, Sensory,	7, Visual	
MATERIALS (next level)	EXISTENCE	AVAILABILITY PRODUCIBILITY	PRODUCIBILITY	RELATIVE COST	REMARKS:
MAIENIALS TYPE:				!	Visible radiation
Cornea Aqueous humor	:				Transmitted by these components
Vitreous humof					
					Traible redistion
Pigment epithelium Rod surface					1 41
Cone surface					
					T4C 1643

File No: 4-80-01

The function aspect of quantize includes an explanation of how the eye determines the amount of visible radiation present. In describing how the Function Information sheet was filled out, the column labeled Object will be discussed first. The Object is found by considering the function of detection which precedes quantization. As soon as the eye has detected the visible radiation, the quantization conversion may begin.

It will be necessary to continue with the resonance hypothesis to explain the quantization conversion that begins in the resonant structures of the surface of the receptors which is where the detection conversion terminates. In the column labeled Object, the energy of the resonant structure is listed.

There are a number of columns on the function sheet that are blank.

These spaces could not be filled in on the subsystem level because the details involved are on the chemical and atomic levels.

When the energies absorbed by the resonating structures become large enough, electrons are dislodged from their bonds and flow from the receptor surface into the receptor proper. Thus the "Convert To" column indicates that the energy has been changed to the kinetic motion of electrons. The quantization is completed by this conversion because the energy of the electrons is in proportion to the activity of the visible radiation that is absorbed by the resonant structure.

File No: 4-80-01

There are a number of drawings called out on the Configuration Information sheet. The first is a functional schematic of quantization, Drawing 4-80-01-1. This illustration is similar in form to the functional schematic of detection that was previously discussed. The quantization conversion takes place in the receptor surface and produces electrons that are transmitted to the receptor proper.

On the following illustration, Drawing 4-80-01-2, the energy dissipation in the eye is shown. Prior to the energy conversion described, visible radiation is dissipated in the components of the eye. The drawing indicates the penetration of 100 quanta at the cornea, and the resulting energy in the parts of the eye.

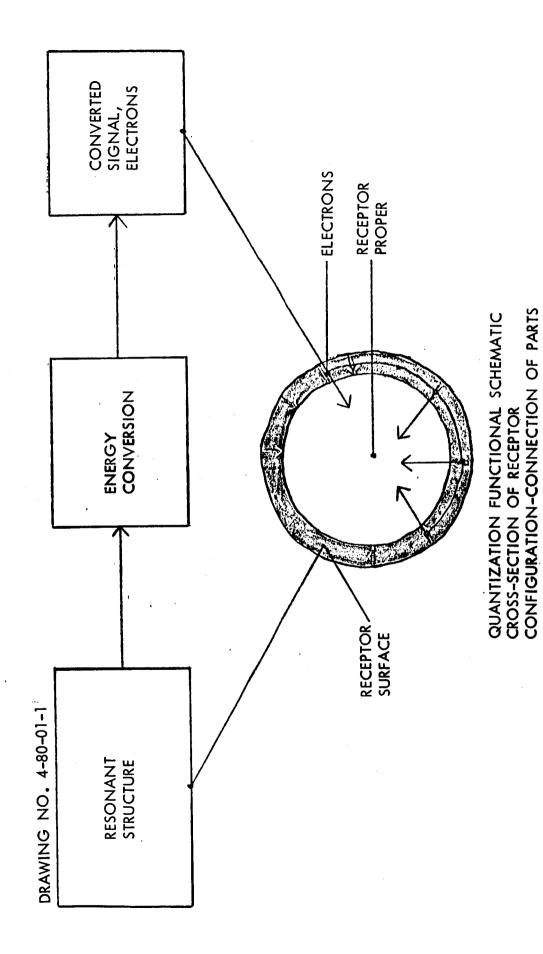
Drawing 4-80-01-3 indicates that quantization of visible radiation begins at the cornea, while Drawing 4-80-01-4 shows that the quantization conversion ends at the interface between the receptor surface and receptor proper.

The Material Information sheet lists the components of the eye involved in the function of quantization.

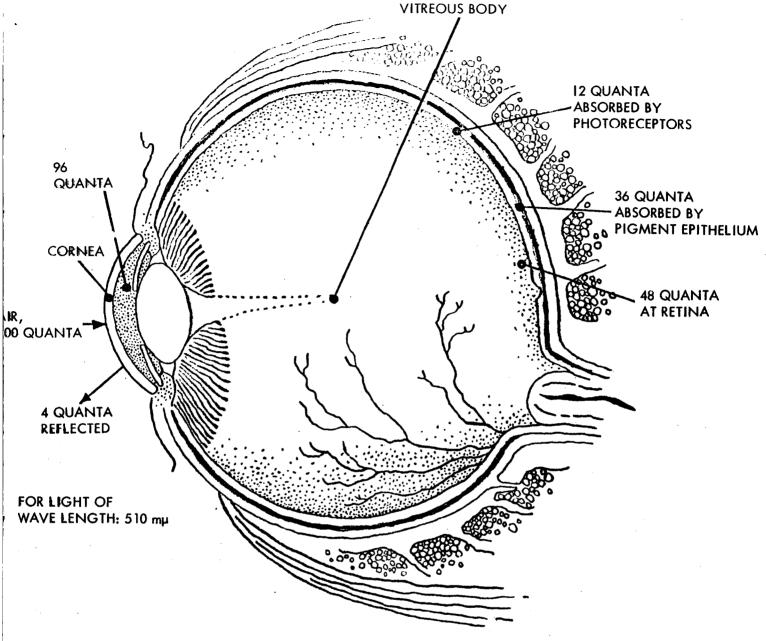
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NOI		METHOD SUB-DETAL NO.2	
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	ı, İnput,	PROPERTY	
	ſ: Man,	PARA- METER	
	ELEMENT:	OBJECT	Energy of resonant structure
	FILE NO: 4-80-01	DEFINITION	ASPECT: Quantize

Parts		Input, Sensory,	SHAPE	MOTION	DEGREES OF FREEDOM	ENVIRONMENT INTERFACE IN	ENVIRONMENT INTERFACE OUT	CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED
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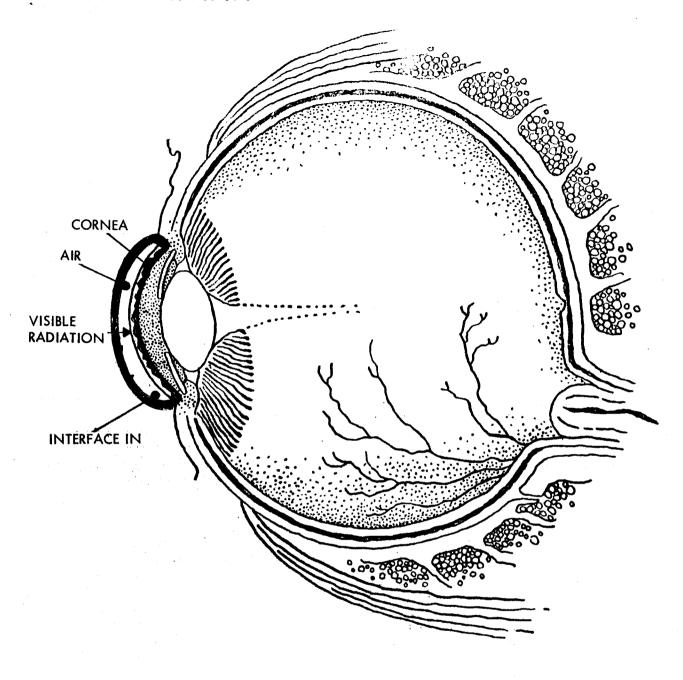
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(DATA SOURCE: HARTRIDGE, H., RECENT ADVANCES IN THE PHYSIOLOGY OF VISION, 1950, p. 24)

ENERGY DISSIPATION IN EYE
QUANTIZATION FUNCTIONAL ASPECT
CONFIGURATION-CONNECTION OF PARTS
DRAWING NO: 4-80-01-2

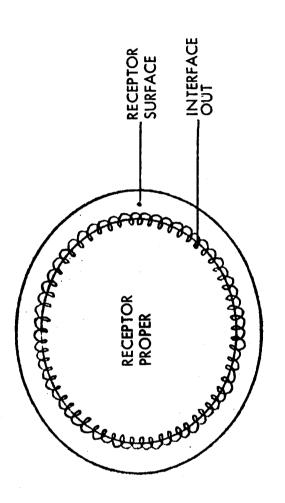
TSC 2218D



CONFIGURATION - INTERFACE IN TRANSVERSE SECTION OF EYE QUANTIZATION FUNCTIONAL ASPECT

DRAWING NO: 4-80-01-3

TSC 2218E



CONFIGURATION - INTERFACE OUT CROSS SECTION OF RECEPTOR QUANTIZATION FUNCTION DRAWING NO: 4-80-01-4

		<b>Y</b>	MATERIAL INFORMATION	INFOR	MATION
FILE NO: 4-80-01	ELEMENT:	Man, Input,	t, Sensory,	Visual	
MATERIALS (next level) MATERIALS	EXISTENCE	AVAILABILITY	PRODUCIBILITY	RELATIVE COST	REMARKS:
TYPE:				**	
Cornea					
Aqueous humor					(Visible radiation transmitted
Tens					and reflected by these components
Vitreous humor					
				11.00	
Pigment epithelium					
Rod					Visible radiation absorbed by these
Cone					components
	,				
*					
					TSC 1643

File No: 4-81-01

An explanation concerned with the determination of what is present in the radiation striking the eye is the subject of the qualification aspect. The qualification conversion begins simultaneously with the detection conversion and precedes the quantization conversion.

In order to fill in the Function Information sheet, the two basic properties of visible radiation - frequency and intensity - should be examined. Frequency filtering cannot be investigated since the environment external to the eye was chosen to be visible radiation and the light sensitive components (rods and cones) of the visual sensor responded to this entire range of excitation. However, it should be realized that penetrating the cornea is a range of frequencies ( $1 \times 10^{14}$  to  $10 \times 10^{14}$  cps, Adler, F. A., Physiology of the Eye, p. 498) that are filtered down to the visible range (4.15 x  $10^{14}$  to 7.56 x  $10^{14}$ , Fulton, J. F., A Textbook of Physiology, p. 446). Relatively transparent portions of the eye which include the cornea, aqueous humor, lens, vitreous body and retina take part in the filtering. These same components also attenuate light intensities as a function of frequency.

Now the column labeled Object on the Function Information sheet may be filled in. "Light frequencies contained in the visible image" is the Object that is converted to light that has experienced intensity attenuation as a function of frequency. The operation is filtering, and subdetail no. 1 is reflection and absorption of light that takes place as radiation penetrates the components of the eye.

File No: 4-81-01

The first drawing listed on the Configuration Information sheet is the Qualification Functional Schematic, Drawing No. 4-81-01-1. As diagramed on this sheet, the light from the visual image is filtered and sent to the resonant structures that are in the rods and cones.

Following this sheet is Drawing No. 4-81-01-2 that indicates the refractive indices of the components of the eye. This drawing shows that visible radiation undergoes modification continuously as it passes through the sensor. As radiation is transmitted through the eye reflection and absorption take place.

The next drawing, number 4-81-01-3, indicates that the qualification function begins at the air-cornea interface. Drawing No. 4-81-01-4 shows that the qualification function terminates at the surface of the receptor.

A listing of the components of the eye involved in qualification is presented on the Material Information sheet.

This file will not discuss how the eye determines the frequency of the light striking the rods and cones. Such a determination involves the perception of color which is a topic that will be examined in the final report.

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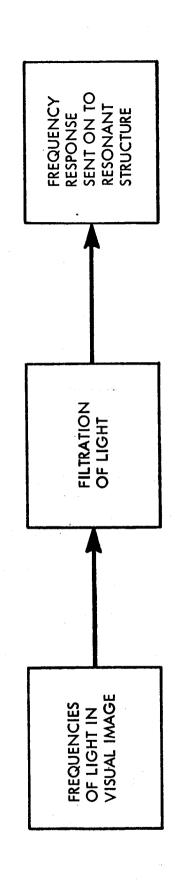
FUNCTION INFORMATION

Man, Input, Sensory, Visual

**ELEMENT:** 

FILE NO: 4-81-01

			CONFIG	CONFIGURATION INFORMATION	INFOR	MATION			
FILE NO :	ELEMENT:	1		Į.	•				
4-81-01		Man, In	Input, Sensory,	y, Visual					
DRAWINGS	ARRANGEMENT	CONNECTION		<del></del>		DEGREES	ENVIRONMENT	ENVIRONMENT	CHANGE WHEN
CONFIGURATION	0 F	96	DIMENSIONS	SHAPE	MOTION	96	INTERFACE	INTERFACE	LIMITS ARE
ASPECT:	PARTS	PARTS		<b>.</b>		FREEDOM	Z	DOUT	EXCEEDED
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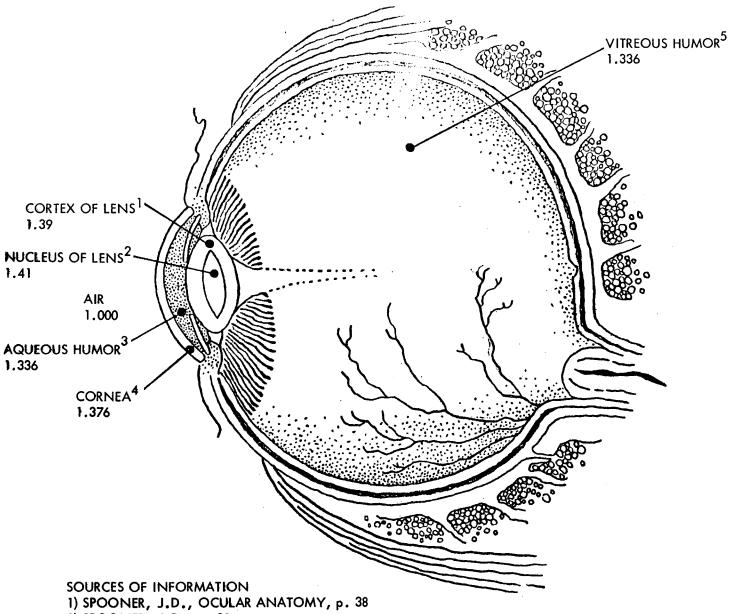


QUALIFICATION FUNCTIONAL SCHEMATIC CONFIGURATION—CONNECTION OF PARTS

DRAWING NO. 4-81-01-1

TSC 2555

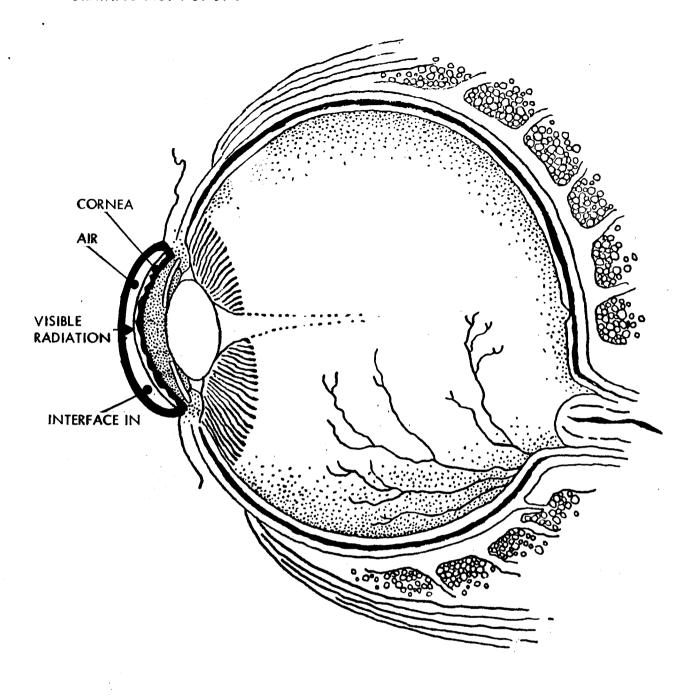
## DRAWING NO: 4-81-01-2



- 2) SPOONER, J.D., p. 38
  3) FULTON, J.F., A TEXTBOOK OF PHYSIOLOGY, p. 427
- 4) ADLER, F.H., PHYSIOLOGY OF THE EYE, p. 43
- 5) FULTON, J.F., p. 427

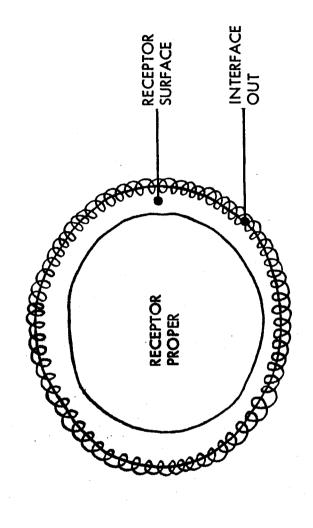
REFRACTIVE INDICES OF THE COMPONENTS OF THE EYE QUALIFICATION FUNCTIONAL ASPECT CONFIGURATION - CONNECTION OF PARTS DRAWING NO: 4-81-01-2

**TSC 2218F** 



ENVIRONMENT-INTERFACE IN TRANSVERSE SECTION OF EYE QUALIFICATION FUNCTIONAL ASPECT

DRAWING NO: 4-81-01-3



CONFIGURATION-INTERFACE OUT CROSS SECTION OF RECEPTOR QUALIFICATION FUNCTIONAL ASPECT

DRAWING ON.: 4-81-01-4

TSC 2527

		>	MATERIAL INFORMATION	INFORA	AATION
FILE NO: 4-81-01	ELEMENT:	Man, Input,	ut, Sensor,	Visual	
MATERIALS (next level)	EXISTENCE			RELATIVE COST	REMARKS:
TYPE:					
cornea					
aqueous humor					
vitreous body					
retina					
lens					
			-		
	-				
					TSC 843

File No: 4-82-01

The functional aspect called transduce deals with the initial energy conversion that takes place in the input portion of the eye. This conversion has been previously discussed while outlining the resonance hypothesis. As shown on the Function Information sheet, the Object is visible radiation which is converted to the kinetic motion of charges. The Operation is the absorption of light energy by the resonant structures in the surface of the receptors.

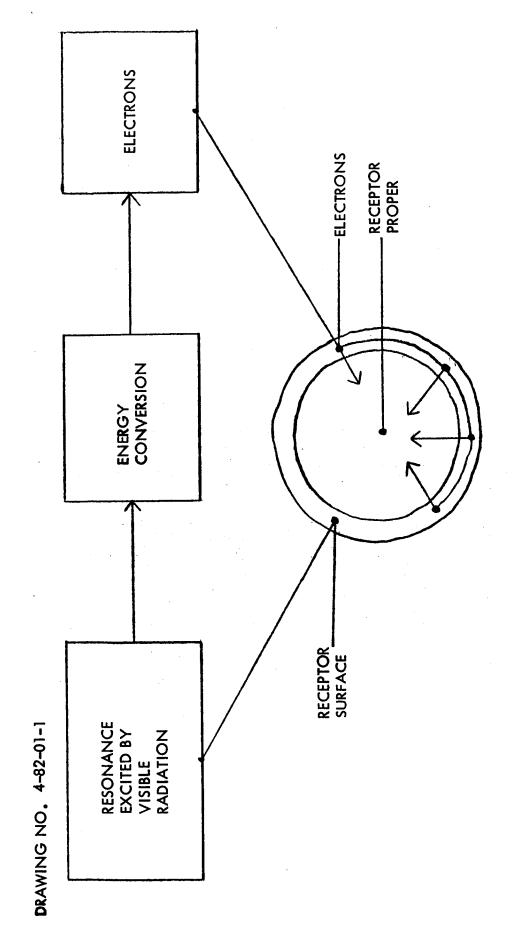
On the Configuration Information sheet, Drawing 4-82-01-1 is called out. This drawing shows a schematic representation of the conversion. Next the drawing, No. 4-82-01-2, of the Interface In is presented. The illustration indicates that the interface is bounded by the vitreous body and the receptor surface. From the central figure on the drawing, it is seen that the vitreous body is in contact with the layer of the eye that contains the rods and cones (the receptors). The layer is called the retina and contains a number of the components of the eye such as the receptors and the pigment epithelium. A drawing, No. 4-82-01-3, of the Interface Out is presented. From the drawing, it may be seen that the interface is bounded by the receptor surface and receptor proper.

A list of the components of the eye that are involved in the transduce function is presented on the Material Information sheet.

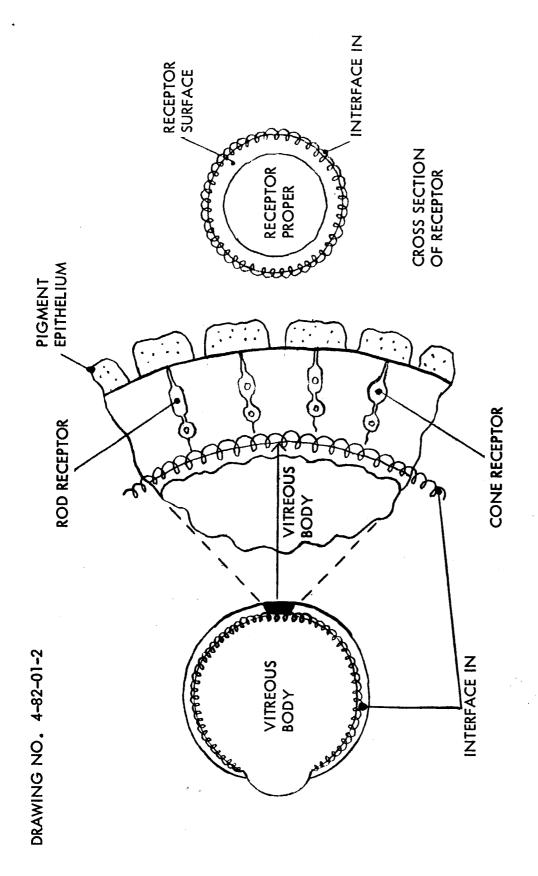
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		MECH- ANISM		
NOI		METHOD SUB-DETAIL NO.2		
CTION INFORMATION		METHOD SUB-DETAIL NO.1		
INFO	Visual	МЕТНОО	conversion of light energy	
CTION	sory,	CONVERT	kinetic motion of elec- trons	
FUN	Input, Sen	CHARACT- ERISTIC	period- icity and ampli- tude	
	Man, In	PROPERTY	freq- uency and inten- sity	
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	FILE NO: 4-82-01	DEFINITION	ASPECT: Transduce	

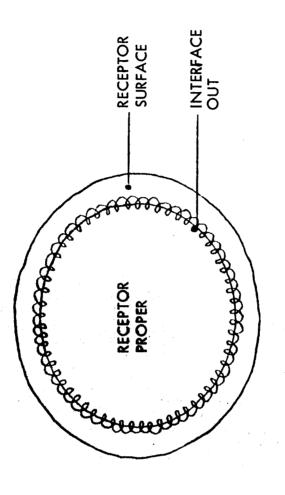
			CONFIG	CONFIGURATION INFORMATION	INFOR	MATION			
FILE NO: 4-82-01	ELEMENT:	Man, Input,	ut, Sensory,	, Visual					
DRAWINGS	ARRANGEMENT	CONNECTION				DEGREES	ENVIRONMENT	ENVIRONMENT	CHANGE WHEN
CONFIGURATION	9		DIMENSIONS	SHAPE	MOTION	0F	INTERFACE	INTERFACE	LIMITS ARE
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TRANSDUCE FUNCTIONAL SCHEMATIC CROSS SECTION OF RECEPTOR CONFIGURATION - CONNECTION OF PARTS DRAWING NO: 4-82-01-1



TRANSVERSE SECTION OF EYE CONFIGURATION - INTERFACE IN TRANSDUCE FUNCTIONAL ASPECT DRAWING NO: 4-82-01-2



CONFIGURATION - INTERFACE OUT CROSS-SECTION OF RECEPTOR TRANSDUCE FUNCTIONAL ASPECT DRAWING NO.: 4-82-01-3

TSC 2526

· File No.: 4-83-01

The Function Information sheet concerned with the aspect of discard noise discusses the threshold level to produce one free electron at the interface between the input and the distribution and control portions of the eye. The purpose of this threshold level is to discard noise signals that are below a specific amplitude. All of the entries on the Function Information sheet have been previously discussed.

Under the column labeled Connection of Parts on the Configuration Information sheet, drawing 4-83-01-1 is called out. The figure is a schematic of the discard noise function. It is shown that if the threshold level of intensity at a specific frequency impinges upon the receptor surface, one electron will be freed and will be transmitted into the receptor proper.

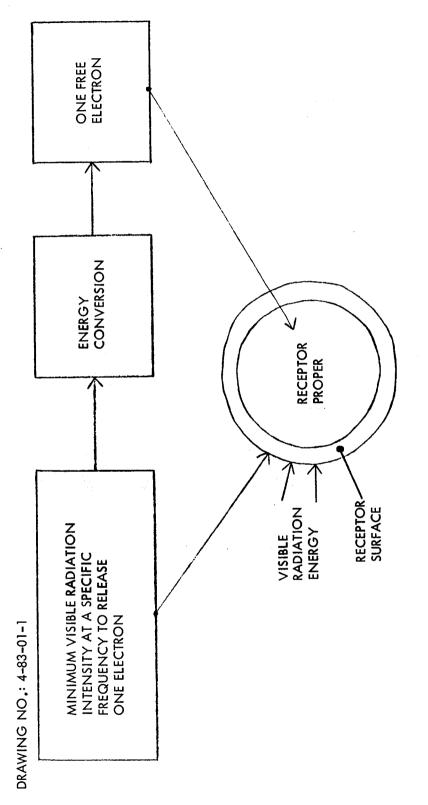
The Interface In, Drawing 4-83-01-2, shows that the vitreous body and receptor proper form the initial boundary of the discard noise function. Electrons that have been produced in the input portion of the eye leave through the Interface Out, Drawing 4-83-01-3, that is bounded by the receptor surface and receptor proper.

On the Material Information sheet, the rods, cones and pigment epithelium are listed as the components that take part in discarding noise.

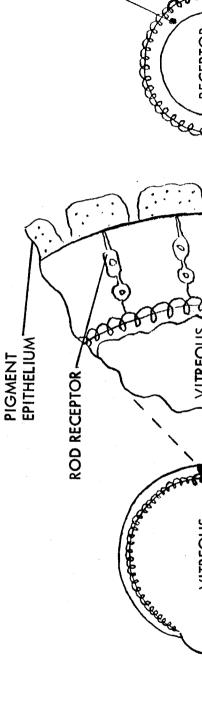
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		CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED		
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		OPERATION OPERATION OPERATION SUB-DETAIL SUB-DETAIL NO. 1 NO. 2		
		OPERATION	accept- ance of visible radia- tion by recep- tors	
		MECH- ANISM		
NOI		METHOD SUB-DETAIL NO.2		
FUNCTION INFORMATION		METHOD SUB-DETAIL NO.1		
I INFO		METHOD	energy con- version in recep- tor	
CTION	Visual	CONVERT	kinetic motion of elec- trons	
FUN	Sensory,	CHARACT- ERISTIC	period- icity	
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	ELEMENT:	ОВЈЕСТ	visible image	
	FILE NO: 4-83-01	DEFINITION	ASPECT: Discard Noise	

			CONFIG	CONFIGURATION INFORMATION	INFOR	MATION			
FILE NO: 4-83-01	ELEMENT:	Man, Input,	ut, Sensory,	, Visual					
DRAWINGS	ARRANGEMENT	CONNECTION				DEGREES	ENVIRONMENT	<b>⊢</b>	CHANGE WHEN TOLERABLE
CONFIGURATION	OF PARTS	OF PARTS	DIMENSIONS	SHAPE	MOTION	OF FREEDOM	INTERFACE	INTERFACE	LIMITS ARE EXCEEDED
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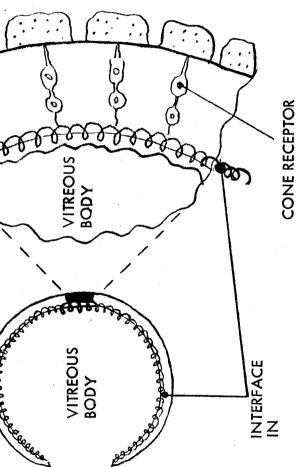


DISCARD NOISE FUNCTIONAL SCHEMATIC CROSS SECTION OF RECEPTOR CONFIGURATION - CONNECTION OF PARTS DRAWING NO: 4-83-01-1



DRAWING NO. 4-83-01-2

RECEPTOR SURFACE

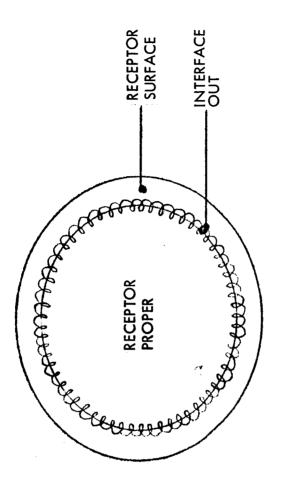


INTERFACE IN

RECEPTOR PROPER CROSS SECTION OF RECEPTORS

TRANSVERSE SECTION OF EYE

CONFIGURATION - INTERFACE IN DISCARD NOISE FUNCTIONAL ASPECT DRAWING NO. 4-83-01-2



CONFIGURATION - INTERFACE OUT CROSS SECTION OF RECEPTOR DISCARD NOISE FUNCTIONAL ASPECT DRAWING NO: 4-83-01-3

File No: 4-84-01

This group of function sheets is concerned with transmitting the information signal from the receptor surface to the receptor proper.

The signal is composed of electrons that are in motion. Transmission is across the interface between the input and the distribution and control portions of the eye.

In the column labeled Object on the Function Information sheet, the electrons that are produced by the initial energy conversion in the eye are listed. The Parameter of moving electrons is velocity and the Property is magnitude and direction. Moving electrons possess the Characteristic of kinetic energy.

There is no change in energy form during transmission. Thus the Convert To column lists moving electrons that are now at the boundary of the receptor surface and receptor proper. The Method of transmission is geometrical proximity that is found when the interface is coated with electrons. Under the column labeled Mechanism, finite recapture time is listed. The Operation of transmission is, of course, the motion of electrons through the interface.

The first drawing, No. 4-84-01-1, listed on the Configuration Information sheet is the transmission functional schematic. Illustrated is the cross section of the receptor with arrows indicating that the electrons travel from the surface to the inner portion of the rods and cones.

On Drawing 4-84-01-2, the Interface In is shown to be bordered by the vitreous body and the receptor surface. The Interface Out, diagrammed on Drawing 4-84-01-3, is bounded by the receptor surface and receptor proper.

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## FUNCTION INFORMATION

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TRANSMIT INFORMATION SIGNAL FUNCTIONAL SCHEMATIC CROSS-SECTION OF RECEPTOR CONFIGURATION-CONNECTION OF PARTS

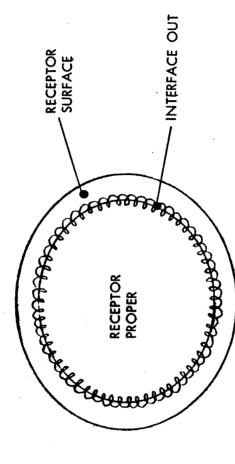
DRAWING NO. 4-84-01-1

DRAWING NO. 4-84-01-2

TRANSVERSE SECTION OF EYE

CONFIGURATION - INTERFACE IN TRANSMIT INFORMATION SIGNAL FUNCTIONAL ASPECT





CONFIGURATION-INTERFACE OUT CROSS-SECTION OF RECEPTOR TRANSMIT INFORMATION SIGNAL FUNCTIONAL ASPECT

DRAWING NO. 4-84-01-3

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File No: 4-90-01

Acceptance of the information signal from the input portion of the eye is the topic for this group of function sheets. The information signal is composed of electrons that are moving from the interface between the input and the distribtion and control segments of the eye. This interface is bordered by the receptor surface layer of cells and the receptor proper. The electrons move through this interface and are captured in the interior of the receptor. The column statements on the Function Information sheet are similar to those found under Transmit Information Signal, File No. 4-84-01 except for the Operation. In accepting the information signal, the Operation is the capture of electrons which takes place in the receptor proper.

The drawing, No. 4-90-01-1, called accept information signal functional schematic is called out on the Configuration Information sheet. On the drawing, it is shown that the electrons are accepted at the border of the receptor surface and the receptor proper. This border is the Interface In which is diagrammed on Drawing 4-90-01-2. From the interface, the electrons move into the interior of the receptor. Acceptance of the electrons is completed when the electrons penetrate the Interface Out, Drawing 4-90-01-3. The Interface Out is just inside the receptor proper.

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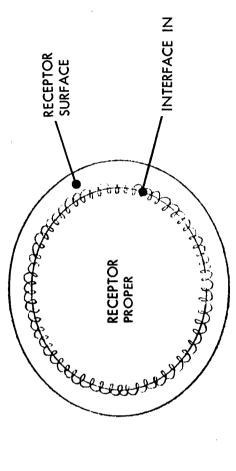
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	ELEMENT:	овлест	moving elec- trons at dis- tribu- ion and control inter- face	
	FILE NO: 4-90-01	DEFINITION	ASPECT: Accept Information Signal	

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DRAWINGS CONFIGURATION	ARRANGEMENT OF	8	DIMENSIONS	SHAPE	NOTION	DEGREES	ENVIRONMENT INTERFACE	ENVIRONMENT INTERFACE	CHANGE WHEN TOLERABLE LIMITS ARE
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ACCEPT INFORMATION SIGNAL FUNCTIONAL SCHEMATIC CROSS-SECTION OF RECEPTOR CONFIGURATION-CONNECTION OF PARTS

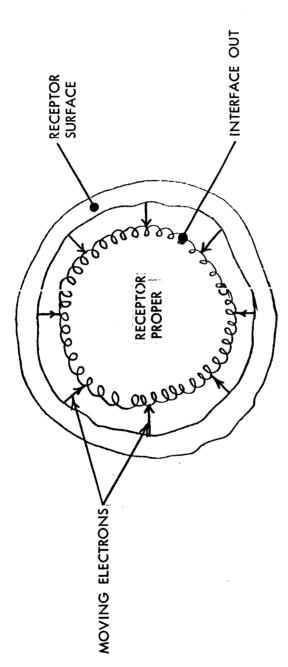
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CONFIGURATION-INTERFACE IN CROSS-SECTION OF RECEPTOR ACCEPT INFORMATION SIGNAL FUNCTIONAL ASPECT

DRAWING NO, 4-90-01-2



CONFIGURATION-INTERFACE OUT CROSS SECTION OF RECEPTCR ACCEPT INFORMATION SIGNAL FUNCTIONAL ASPECT

DRAWING NO.4-90-01-3

		~	MATERIAL		INFORMATION	·
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File No: 4-91-01

This group of information sheets deals with the internal control signals received by the distribution and control portion of the eye. An investigation of the internal control signal was carried out, and it was learned that centrifugal fibers receive these signals which are believed to originate in the brain. These signals in the form of electric pulses are accepted by the centrifugal fibers and transmitted to the centrifugal bipolar cells; then the centrifugal bipolar cells relay the electric pulse to the photoreceptors. This internal control signal may be used by the brain to produce either inhibition or facilitation of the centrifugal bipolar cell or one of its associated cells.

From the above description, the columns on the Function Information sheet may be filled out. The Object is the electric pulse that originates from the brain. The pulse is not converted to another energy form, but is transmitted along the centrifugal fiber. The Method of transmission is the absorption of ions since transverse ion flow is the mode of transmission along a nerve fiber. In the column labeled Operation, the acceptance of an electric pulse by the centrifugal fiber is listed.

On the Configuration Information sheet, the first drawing, No. 4-91-01-1, called out diagrams the flow of electric pulses to and from the centrifugal fibers. It may be seen that the internal control signal begins in the brain, moves along the centrifugal fiber and then is transmitted to the centrifugal bipolar cell.

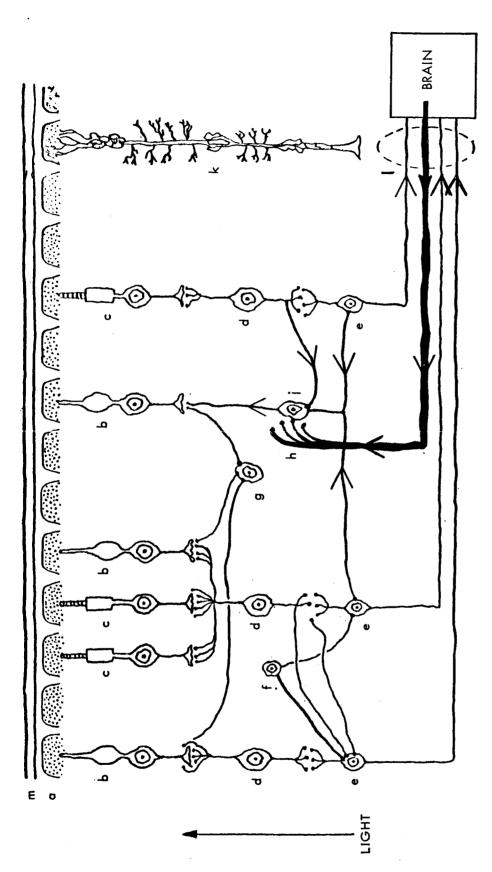
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The next drawing, No. 4-91-01-2, indicates that the Interface In is at the point where the brain transmits the signal to the centrifugal fiber. Drawing 4-91-01-3 shows that the Interface Out is formed by the centrifugal fiber and the centrifugal bipolar cell. Only the centrifugal fiber is listed on the Material Information sheet as the component of the eye that accepts the internal control signal.

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		CHANGE WHEN WHEN TOLERABLE LIMITS ARE EXCEEDED	
		OPERATION SUB-DETAIL NO. 2	
		OPERATION OPERATION OPERATION SUB-DETAIL SUB-DETAIL NO. 2 NO. 1	
		OPERATION	accept- ance of elec- tric pulse
		MECH- ANISM	
NOI		METHOD SUB-DETAIL NO.2	
FUNCTION INFORMATION		METHOD SUB-DETAIL NO.1	
INFO	Visual	9	absorp- tion of ions
CTION	Sensorv, V	1 5	elec- tric pulse in cen- trifu- gal fiber
FUN	Input. Sen	CHAR	
	Man. In		
		PARA- METER	
	ELEMENT:	ОВЈЕСТ	electrric pulse from brain
	FILE NO:	DEFINITION	ASPECT: Accept Internal Control Signal

			CONFIG	NFIGURATION INFORMATION	INFOR	MATION			
FILE NO: 4-91-01	ELEMENT:	Man, Input,	out, Sensory,	y, Visual					
DRAWINGS	ARRANGEMENT	CONNECTION				DEGREES	ENVIRONMENT	ENVIRONMENT	CHANGE WHEN
CONFIGURATION	0 F	0	DIMENSIONS	SHAPE	MOTION	96	INTERFACE	INTERFACE	TOLERABLE
ASPECT:	PARTS	PARTS				FREEDOM	٤	00T	LIMITS ARE EXCEEDED
Parts		flow of					brain	centri-	
		elec-					j-	fugal	
		tric						fibers -	
		pulses					,,	centri-	
		Drawing					Drawing	fugal	
		No:					No:	bipolar	
		4-91-01-1					4-91-01-2	-2cells	
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								No:	
								4-91-01-3	
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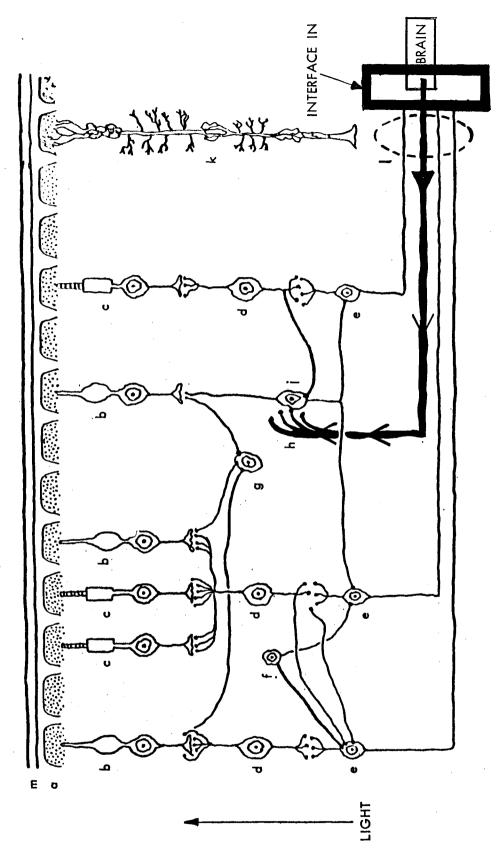
THE RETINA

k MULLER FIBER
I OPTIC NERVE
B CHOROID CENTRIFUGAL FIBER 9 HORIZONTAL CELL h CENTPIFIT CENTRIFUGAL BIPOLAR CELL GANGLION CELL BIPOLAR CELL d CENTRIPETAL PIGMENT EPITHELIUM b CONE

f AMACRINE CELL.

FLOW OF ELECTRIC PULSES TO AND FROM CENTRIFUGAL FIBERS ACCEPT INTERNAL CONTROL SIGNAL FUNCTIONAL ASPECT CONFIGURATION-CONNECTION OF PARTS

-103-



THE RETINA

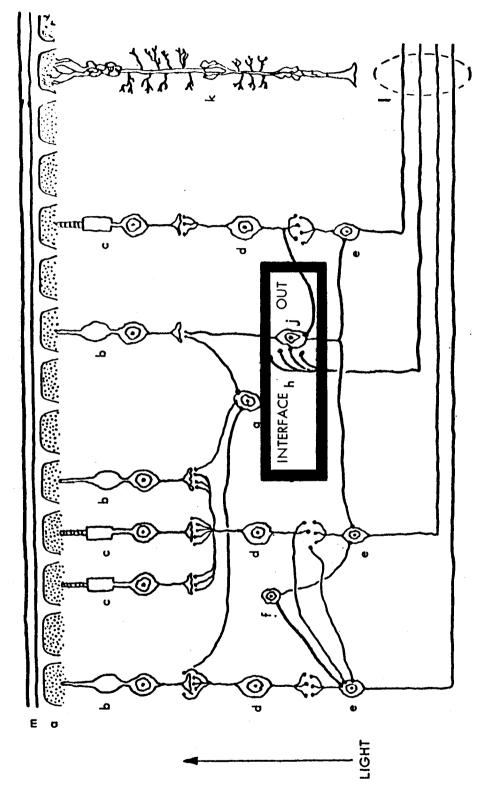
o PIGMENT EPITHELIUM d CENTRIPETAL 9 HORIZONTAL CELL
b CONE BIPOLAR CELL h CENTRIFUGAL FIBER
c ROD e GANGLION CELL ; CENTRIFUGAL
f AMACRINE CELL BIPOLAR CELL

k MULLER FIBER I OPTIC NERVE B CHOROID

CONFIGURATION-INTERFACE IN ACCEPT INTERNAL CONTROL'SIGNAL FUNCTIONAL ASPECT

DRAWING NO. 4-91-01-2

-104-



THE RETINA

d CENTRIPETAL a PIGMENT EPITHELIUMb CONEc ROD

9 HORIZONTAL CELL h CENTRIFUGAL FIBER CENTRIFUGAL BIPOLAR CELL
GANGLION CELL
FAMACRINE CELL

k MULLER FIBER I OPTIC NERVE ■ CHOROID

BIPOLAR CELL

ACCEPT INTERNAL CONTROL SIGNAL FUNCTIONAL ASPECT CONFIGURATION-INTERFACE OUT

DRAWING NO. 4-91-01-3

-105-

		*	MATERIAL INFORMATION	INFOR	MATION
FILE NO:	ELEMENT:	Man, Inpu	Input Sensory Visual	'i sua l	
4-91-01 MATERIALS (next level)	EXISTENCE	AVAILABILITY	PRODUCIBILITY	RELATIVE COST	REMARKS:
TYPE:					
centrifugal fibers					
					\$100 A.C.
					7
	-				
					TSC 1643

File No: 4-92-01

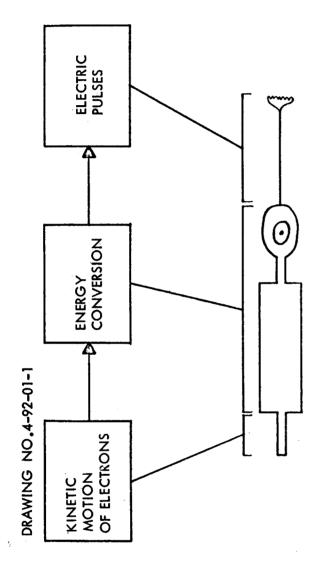
The functional aspect called Convert Information Signal describes the modification of the energy of the moving electrons that have entered the interior of the receptor. On the Function Information sheet, the Object listed as the information signal is the kinetic motion of electrons. In the receptor, the energy of these electrons is used to produce electric pulses; thus, the Convert To column shows electric pulses. The Operation was the conversion of energy in the receptors.

A drawing, No. 4-92-01-1, called Convert Information Signal Functional Schematic is listed on the Configuration Information sheet. The transverse section of a receptor (rod or cone) is shown and the energy conversion is diagrammed. Next Drawing 4-92-01-2 illustrates the Interface In. At the boundary between the receptor surface and receptor proper, the conversion of the information signal begins. Drawing 4-92-01-3 indicates that the electric pulses produced in the receptors are transmitted to the centripetal bipolar, centrifugal bipolar and horizontal cells.

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		_	NON-CONDUCTORS	125		+	+	+	+	╈	$\top$	T	T		Τ													$\perp$		L	L	┺	_
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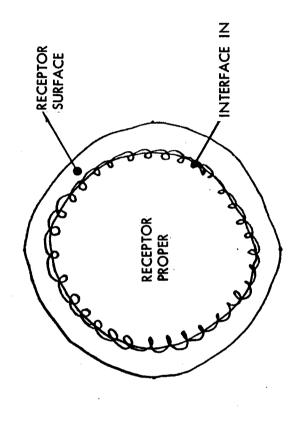
•		CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED		
		OPERATION SUB-DETAIL NO. 2		
		OPERATION OPERATION OPERATION SUB-DETAIL SUB-DETAIL NO. 1 NO. 2	<b>.</b>	
		OPERATION	conver- sion of energy in recep tor	
		MECH- ANISM		
NOI	•	METHOD SUB-DETAIL NO.2		
FUNCTION INFORMATION		METHOD SUB-DETAIL NO.1		
INFO	Visual	METHOD		
CTION	i	CONVERT TO	elec- tric pulses	
FUN	ıt, Sensory,	CHARACT- ERISTIC		
	Man, Input,	PROPERTY		
		PARA- METER		
	ELEMENT:	OBJECT	information signal, kinetic motion of electrons	
	FILE NO: 4-92-01	DEFINITION	ASPECT: Convert infol Information tion Signal sign kine moti of el tron	

			CONFIG	CONFIGURATION INFORMATION	INFOR	MATION			
FILE NO::	ELEMENT:	Man Input	Sensorv.	Visual					
DRAWINGS			1						CHANGE WHEN
CONFIGURATION	ARRANGEMENT	CONNECTION	DIMENSIONS	SHAPE	MOTION	DEGREES	INTERFACE	INTERFACE	TOLERABLE
ASPECT:	PARTS	PARTS				FREEDOM	Z	out	EXCEEDED
D2 * + 0		Convert					receptor	receptor	
21181		informa-					surface-	proper-	
		tion					receptor	centri-	
		signal						petal	
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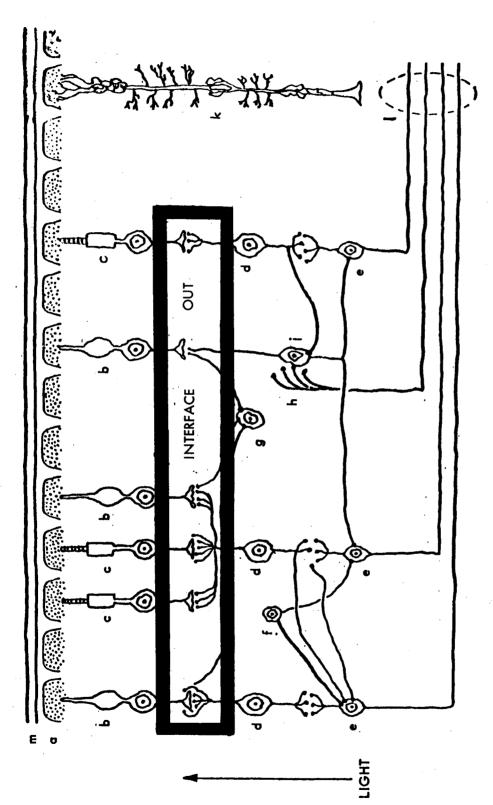
CONVERT INFORMATION SIGNAL FUNCTIONAL SCHEMATIC TRANSVERSE SECTION OF RECEPTOR CONFUGURATION-CONNECTION OF PARTS

DRAWING NO. 4-92-01-1 TSC2548



CONFIGURATION – INTERFACE IN CROSS SECTION OF RECEPTORS CONVERT INFORMATION SIGNAL FUNCTIONAL ASPECT

DRAWING NO. 4-92-01-2



THE RETINA

9 HORIZONTAL CELL a PIGMENT EPITHELIUM b CONE

d CENTRIPETAL
BIPOLAR CELL
GANGLION CELL
f AMACRINE CELL

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k MULLER FIBER
I OPTIC NERVE
a CHOROID

CENTRIFUGAL FIBER CENTRIFUGAL BIPOLAR CELL

CONVERT INFORMATION SIGNAL FUNCTIONAL ASPECT CONFIGURATION-INTERFACE OUT

DRAWING NO. 4-92-01-3

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MATERIAL INFORMATION	Sensory,																	
W	Man, Input,	AVAIL ABILITY PRODUCIBILITY									-		,					
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File No: 4-93-01

At the subsystem level no stored signal is in evidence in the distribution and control portion of the eye. Thus, the sheets explaining the correlation of the converted information signal and the stored signal do not contain details of the materials that are involved nor are any drawings under the configuration heading presented. At some lower level, the correlation of the converted signal with the stored signal can be examined.

The Function Information sheet simply outlines the aspect.

Under Object, the converted information signal is listed. This signal is converted to a stored signal. The Operation is the correlation of signals.

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	: Man,	PARA- METER	
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	FILE NO: 4-93-01	DEFINITION	ASPECT: Correlate Converted Signal to Store

			CONFIG	NFIGURATION		INFORMATION			
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DRAWINGS CONFIGURATION ASPECT:	ARRANGEMENT OF PARTS	CONNECTION OF PARTS	DIMENSIONS	SHAPE	MOTION	DEGREES OF FREEDOM	ENVIRONMENT INTERFACE IN	ENVIRONMENT INTERFACE OUT	CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED
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File No: 4-94-01

No stored signal was found on the subsystem level in the distribution and control portion of the eye; therefore, the function that converts the stored signal to the decoded signal cannot be explained at this level. Thus the configuration and material sheets are not filled in, and the Function Information Sheet gives only a general indication of the conversion that takes place.

The Object is the stored signal which is converted to the decoded signal. It is known that the signal leaving the distribution and control portion of the eye (See File No. 4-78-01) is composed of electric pulses. These pulses, listed under the Convert To column, comprise the decoded signal. The Operation is the conversion of energy.

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	Man, Input,	PROPERTY	
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	ELEMENT:	OBJECT	signal
	FILE NO: 4-94-01	DEFINITION	ASPECT: Convert Stored Signal to Decode

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This group of function sheets is concerned with transmitting the decoded signal from the secondary neuron (the dendrite and nucleus of the ganglion cell) to the optic nerve (the axon of the ganglion cell). The decoded signal is formed of ions that are flowing in a transverse fashion. Signal transmission is across the interface between the distribution and control and the output portions of the eye.

The Function Information sheet is similar to the form used to describe the transmission of the information signal (4-84-01) except that the decoded signal is transmitted by means of transverse ion flow. These ions are listed in the Object and Convert To columns. As in the case of the information signal, there is no change in the energy form of the object.

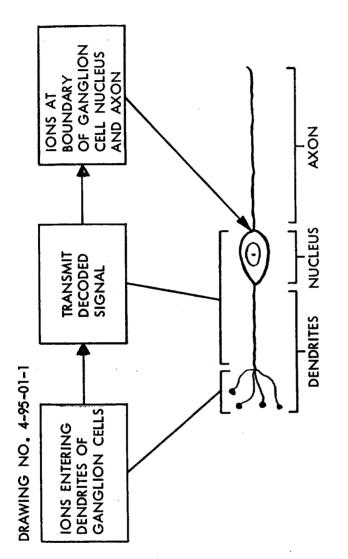
A drawing, No. 4-95-01-1, diagramming the transmission is listed on the Configuration Information sheet. On the drawing, a transverse section of a ganglion cell is shown and the location of the steps in transmission are pointed out. Next, Drawing No. 4-95-01-2 diagrams the Interface In. Three types of cells are shown to transmit a signal to the ganglion cell. These are the centripetal and centrifugal bipolar cells as well as the amacrine cell. Between the Interface In and the Interface Out the transmission of ions is completed. Drawing 4-95-01-3 indicates that the Interface Out is bordered by the ganglion cell nucleus and the optic nerve.

On the Material Information sheet are listed the components of the eye that take part in the transmission of the decoded signal.

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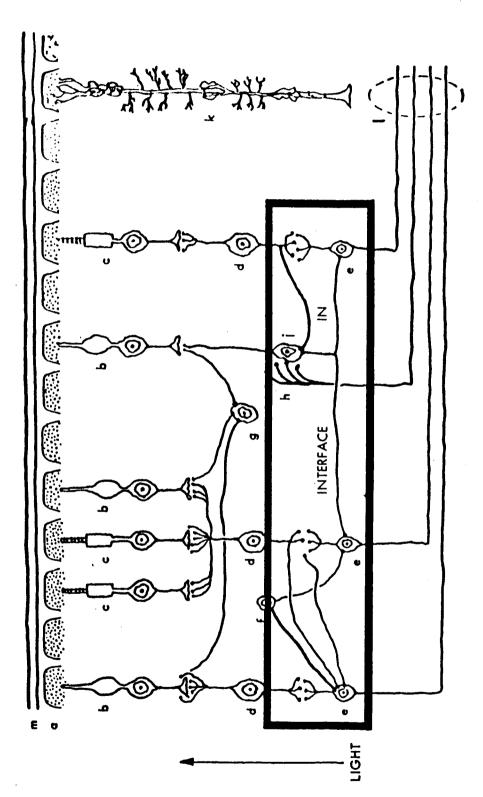
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TRANSMIT DECODED SIGNAL FUNCTIONAL SCHEMATIC TRANSVERSE SECTION OF GANGLION CELL

DRAWING NO. 4-95-01-1 TSC2547



THE RETINA

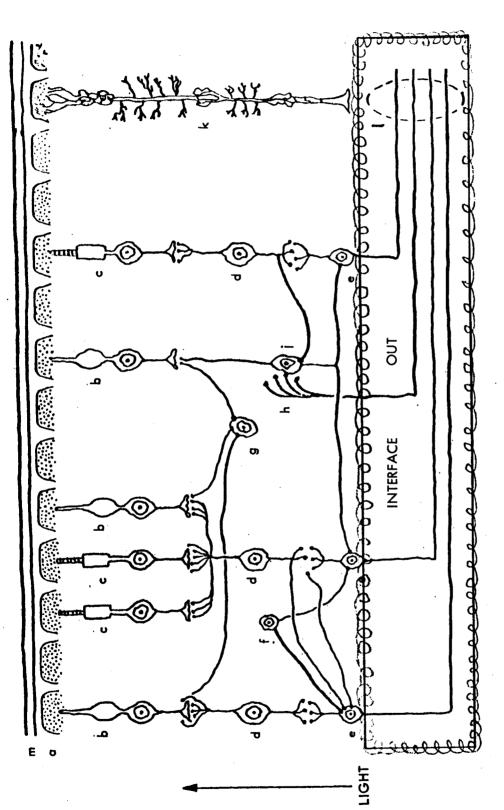
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b CONE
c ROD

k MULLER FIBER I OPTIC NERVE T CHOROID

F AMACINE CELL

CONFIGURATION-INTERFACE IN
TRANSMIT DECODED SIGNAL FUNCTIONAL ASPECT

DRAWING NO. 4-95-01-2



THE RETINA

k MULLER FIBER
I OPTIC NERVE
m CHOROID CENTRIFUGAL FIBER CENTRIFUGAL BIPOLAR CELL HORIZONTAL CELL GANGLION CELL BIPOLAR CELL CENTRIPETAL o PIGMENT EPITHELIUM
b CONE
c ROD

AMACRINE CELL

CONFIGURATION-INTERFACE OUT TRANSMIT DECODED SIGNAL FUNCTIONAL ASPECT DRAWING NO. 4-95-01-3

File No.: 4-102-01

Acceptance of the decoded signal from the distribution and control portion of the eye is the subject for this group of function sheets. The decoded signal is composed of transverse ion flow that is moving from the interface between the distribution and control and the output segments of the eye. These segments are bounded by ganglion cell nucleus (the secondary neuron) and the ganglion cell axon (the optic nerve). The statements in the columns on the Function Information sheet have been previously discussed.

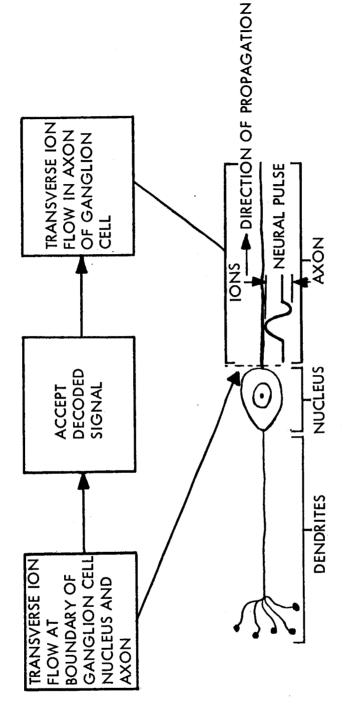
On the Configuration Information sheet, it may be seen that the first drawing is Accept Decoded Signal Functional Schematic. This drawing, No. 4-102-01-1, presents a transverse section of a ganglion cell and indicates the location of the ions that are accepted. Following this figure is Drawing 4-102-01-2 that shows the Interface In. The interface is bounded by the ganglion cell nucleus and the ganglion cell axon. The final drawing, No. 4-102-01-3, in the file depicts the Interface Out. It is shown that this interface is bordered by the ganglion cell axon (optic nerve) and the lateral geniculate bodies which are the first neurons of the nervous subsystem that the eye excites. Each optic nerve fiber stimulates five or six lateral geniculate neuron cells.

The Material Information sheet lists the ganglion cell and the optic nerve as the components involved in the acceptance of ions.

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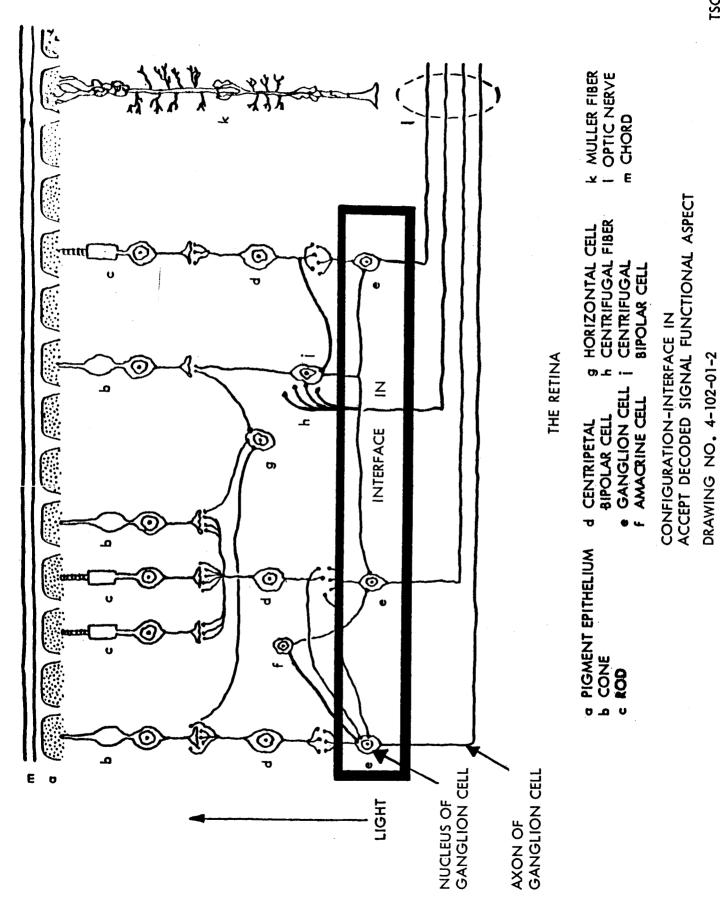
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			CONFIG	ONFIGURATION		INFORMATION			
FILE NO:	ELEMENT:	Man, Input	Man, Input, Sensory, Visual	Visual					
4-102-01 DRAWINGS	ARRANGEMENT	CONNECTION				DEGREES	ENVIRONMENT	<b>-</b>	CHANGE WHEN TOLERABLE
CONFIGURATION ASPECT:	OF PARTS	OF PARTS	DIMENSIONS	SHAPE	MOTION	OF FREEDOM	INTERFACE	INTERFACE	LIMITS ARE EXCEEDED
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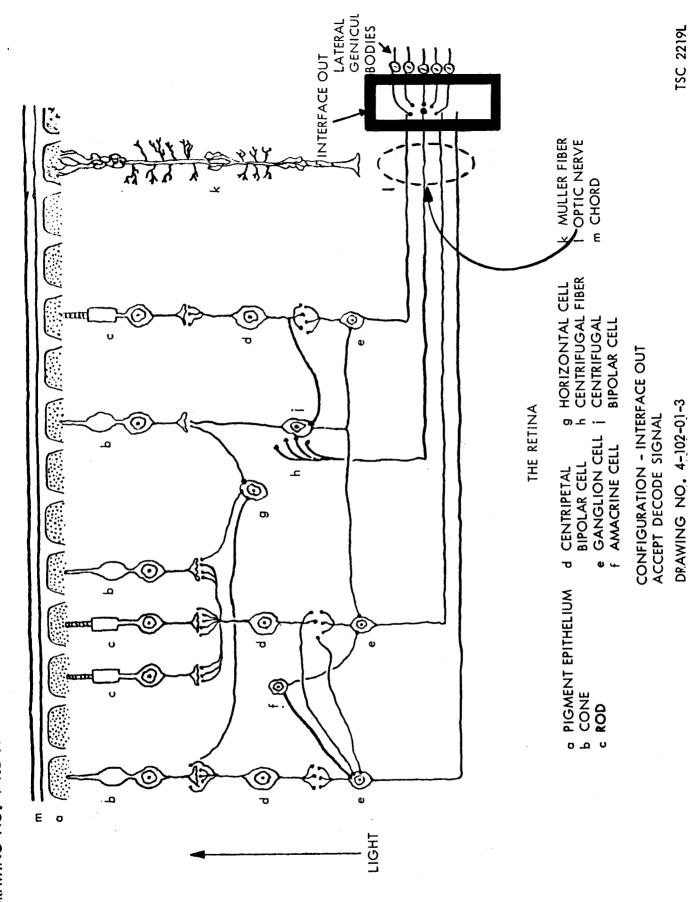


ACCEPT DECODED SIGNAL FUNCTIONAL SCHEMATIC TRANSVERSE SECTION OF GANGLION CELL

DRAWING NO: 4-102-01-1 TSC 25



-138-



		*	MATERIAL INFORMATION	INFOR	MATION
FILE NO:	ELEMENT:	Man, Input	Input, Sensory, Visual	Visual	
4-102-01 MATERIALS (next level)	EXISTENCE	AVAILABILITY	PRODUCIBILITY	RELATIVE COST	REMARKS:
TYPE:					
ganglion cell					
nucleus					
axon of ganglion					
cell (optic nerve)					
·					
					TSC 1643

File No: 4-103-01

The functional aspect covers the conversion of the decoded signal to the action signal. Examination of the optic nerve indicates that the decoded signal entering is composed of neural pulses and the exiting action signal is also pulses. Thus the Object and Convert To columns on the Function Information sheet both list neural pulses.

As the Configuration Information sheet indicates, the location of the conversion from decoded to action signal takes place within the optic nerve; therefore, no drawings of the Interface In and Interface Out were made.

The only component shown on the Material Information sheet is the optic nerve.

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		CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED	
		OPERATION SUB-DETAIL NO. 2	
		OPERATION OPERATION OPERATION SUB-DETAIL SUB-DETAIL NO. 1 NO. 2	
		OPERATION	propa-gation of signal
		MECH- ANISM	
NOI		METHOD SUB-DETAIL NO.2	
INFORMATION		METHOD SUB-DETAIL NO.1	
INFO	al	МЕТНОБ	
FUNCTION	y, Visual	CONVERT	action signal- neural pulses
FUN	, Sensory,	Ü	
	n, Input,	PROPERTY	
	ſ: Man,	PARA- METER	
	ELEMENT:	овлест	decoded signal- neural pulses
	FILE NO: 4-103-01	DEFINITION	ASPECT: Convert to action

		,	CONFIG	URATION	CONFIGURATION INFORMATION	MATION			
FILE NO: 4-103-01	ELEMENT:	Man, Input,	1	Sensory, Visual					
DRAWINGS CONFIGURATION ASPECT:	ARRANGEMENT OF PARTS	CONNECTION OF PARTS	DIMENSIONS	SHAPE	MOTION	DEGREES OF FREEDOM	ENVIRONMENT INTERFACE IN	ENVIRONMENT INTERFACE OUT	CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED
							internal	internal	
							to optic	to optic	
							nerve	nerve	
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									TSC 1641

FILE NO: 4-103-01  MATERIALS  MATERIALS  TYPE:  Optic nerve  Optic nerve			*	MATERIAL INFORMATION	INFORA	MATION
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c nerve	1		AVAILABILITY	PRODUCIBILITY	RELATIVE COST	REMARKS:
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	tic nerve					
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File No.: 4-104-01

This functional aspect is concerned with correlating the stored signal with the action signal. At the subsystem level, no correlation of the action signal with a stored signal is apparent. The Function Information sheet only contains a statement that this correlation takes place, but no details are supplied. This sheet indicates that the Object is the action signal which undergoes correlation, but does not change in energy form.

On the Configuration Information sheet, both the Interface In and Out are shown to be internal to the optic nerve. This indicates that the correlation of the action signal with the stored signal takes place within the optic nerve.

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		CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED		
		OPERATION SUB-DETAIL NO. 2		
		OPERATION OPERATION OPERATION SUB-DETAIL SUB-DETAIL NO. 2 NO. 1		
		OPERATION	correl- ation of signal	
		MECH- ANISM		
NOI		METHOD SUB-DETAIL NO.2		
FUNCTION INFORMATION		METHOD SUB-DETAIL NO.1		
INFO		METHOD		
CTION	, Visual	CONVERT	signal	
FUN	Sensory	CHARACT- ERISTIC		
	Man, Input,	PROPERTY		
		PARA- METER		
	ELEMENT:	овјест	action signal	
	FILE NO: 4-104-01	DEFINITION	ASPECT: Correlate with store	

		>	MATERIAL INFORMATION	INFOR	MATION
FILE NO:	ELEMENT: Man,	Inpu	Input, Sensory, Visual	Visual	
4-104-01 MATERIALS (next level)	EXISTENCE	AVAILABILITY	PRODUCIBILITY	RELATIVE	REMARKS:
MATERIALS TYPE:					
optic nerve					
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File No: 4-105-01

This functional aspect discusses the transmission of the action signal from the output portion of the eye to the first neuron encountered in the nervous subsystem. The column labeled Object on the Function Information sheet lists the electric pulses in the optic nerve. These pulses compose the action signal in the output portion of the eye.

The functional aspect of transmission does not alter the energy form of the object and thus the Convert To column lists electric pulses that have entered the lateral geniculate bodies. Under the column headed Operation, the spacial displacement of the electric pulse is mentioned.

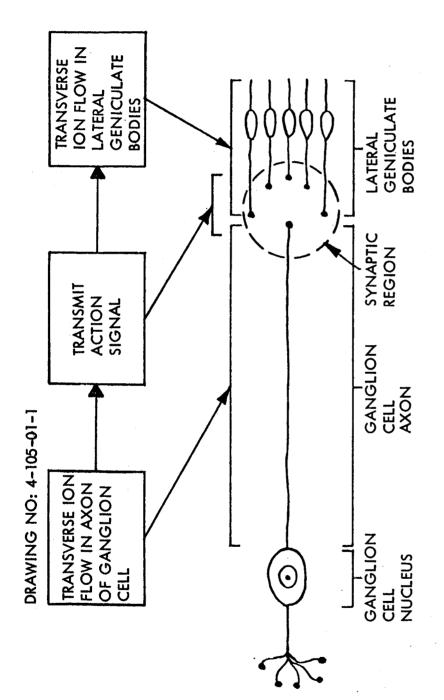
The first drawing, No. 4-105-01-1, listed on the Configuration Information Sheet is titled Transmit Action Signal Functional Schematic. Transverse sections of a ganglion cell and a number of lateral geniculate bodies are shown. On the second drawing, No. 4-105-01-2, in this file, the Interface In is shown. Bordering the interface are the nucleus of the ganglion cell and the axon of the ganglion cell (optic nerve). The other end of the optic nerve forms one of the boundaries of the Interface Out diagrammed on Drawing 4-105-01-3. The other components of the boundary are the lateral geniculate bodies.

On the Material Information sheet, the components of the eye involved in the transmission of the action signal are listed.

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	FILE NO: 4105-01	DEFINITION	ASPECT: Transmit action signal

			CONFIG	NFIGURATION	INFOR	INFORMATION			
FILE NO:	ELEMENT:	Man, Input,	, Sensory, Visual	Visual					
DRAWINGS CONFIGURATION ASPECT:	ARRANGEMENT OF PARTS	CONNECTION OF PARTS	DIMENSIONS	SHAPE	MOTION	DEGREES OF FREEDOM	ENVIRONMENT INTERFACE IN	ENVIRONMENT INTERFACE OUT	CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED
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		schematic Drawing					ganglion cell	geniculate bodies	
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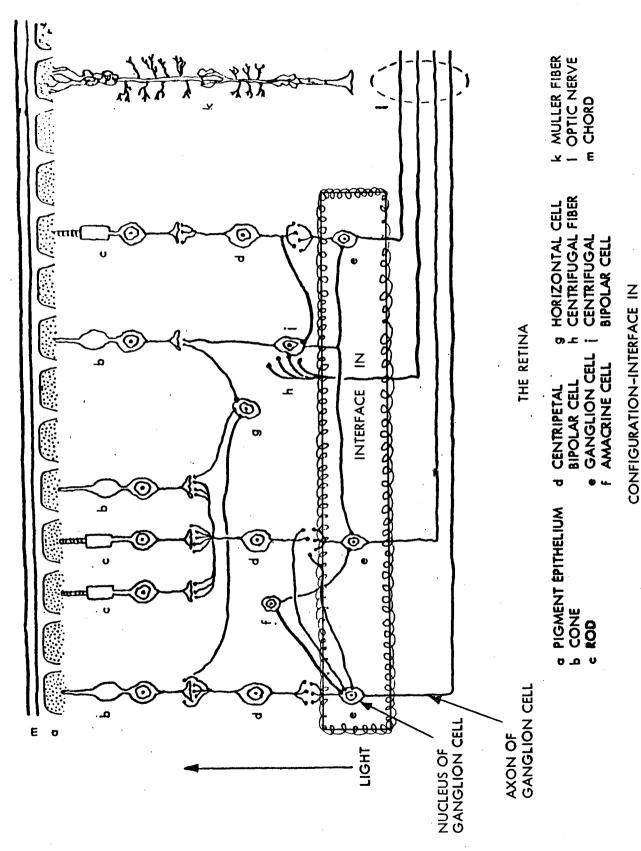


TRANSMIT ACTION SIGNAL FUNCTIONAL SCHEMATIC TRANSVERSE SECTION OF GANGLION CELL AND LATERAL GENICULATE BODIES CONFIGURATION - CONNECTION OF PARTS

DRAWING NO: 4-105-01-1, TSC 2545

TRANSMIT ACTION SIGNAL FUNCTIONAL ASPECT

DRAWING NO. 4-105-01-2



DRAWING NO. 4-105-01-3

DRAWING NO. 4-105-01-3

MATERIAL INFORMATION  ILE NO: ELEMENT: Man, Input, Sensory, Visual 4-105-01  Autrenals  Interal  geniculate bodies  Relation  Geniculate bodies  AMERICAL  A						
ELEMENT: Man, Input, Sensory, Visual  MALS  TALE  SEVE  ALE bodies			<b>≥</b>	ATERIAL	I NFOR/	MATION
ATERIALS  THE TATE  THE TA	FILE NO: 4-105-01	ELEMENT:		t, Sensory,	Visual	
ral culate bodies	MATERIALS (next level) MATERIALS	EXISTENCE	AVAILABILITY	PRODUCIBILITY	RELATIVE COST	REMARKS:
	TYPE:					
		9				
	optic nerve					
	lateral					
	geniculate bodies					

File No: 4-111-01

This is the first file under the influencing factor of configuration. File 4-111-01 is for the aspect called parts. On the Configuration Information sheet the column headed Aspect calls out parts. The sheet is a listing of drawings and does not present data.

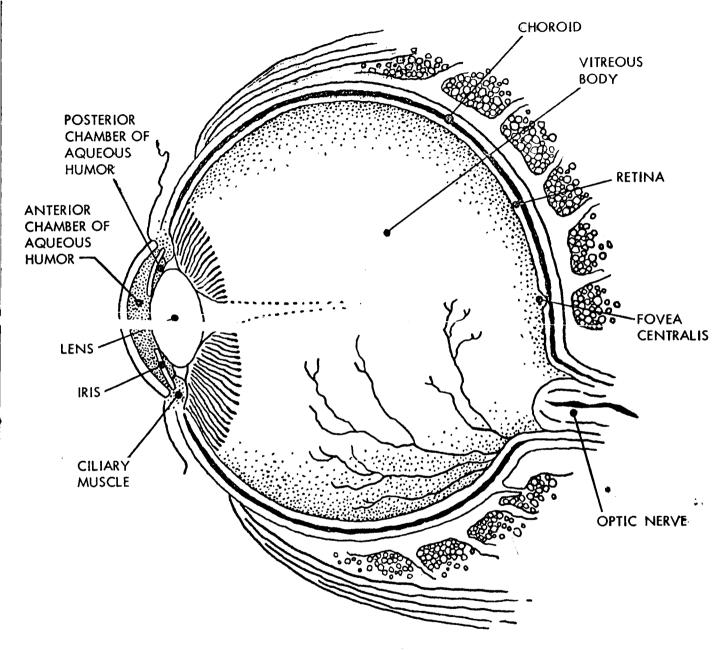
Two drawings, No. 4-111-01-1 and -2, are called out in the column Arrangement of Parts. These two drawings also show the Connection of Parts. The drawings present an anatomical view of the eye. Next Drawings 4-111-01-3 and -4 give the dimensions of the eyeball and the retina respectively. Drawing 4-111-01-4 indicates that the retina covers an area of 266 mm<sup>2</sup>. The retina roughly covers five-sixths of a sphere which is one inch in diameter.

On Drawing 4-111-01-5, the Interface In is shown. The figure indicates that the cornea is the part of the eye that first receives visible radiation. In viewing the Interface Out, Drawing 4-111-01-6, it is seen that the optic nerve and lateral geniculate bodies form the boundary. This is the boundary where the action signal leaves the eye and enters the nervous subsystem.

The Material Information sheet lists the parts of the eye.

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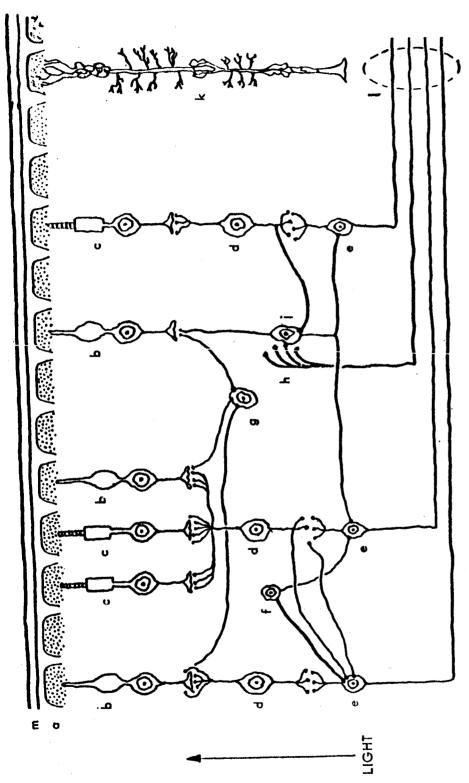
			CONFIG	ONFIGURATION INFORMATION	INFOR	MATION			
FILE NO:: 4-111-01	ELEMENT:	ELEMENT: Man, Input,	, Sensory,	Visual					
DRAWINGS CONFIGURATION ASPECT:	ARRANGEMENT OF PARTS	CONNECTION OF PARTS	DIMENSIONS	SHAPE	MOTION	DEGREES OF FREEDOM	ENVIRONMENT INTERFACE IN	ENVIRONMENT INTERFACE OUT	CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED
Parts	Drawing No.	Drawing No.	Drawing No.	Drawing No.			air-cornea Drawing		
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								bodies 4-111-01-6	
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(SOURCE, ATLAS OF HUMAN BODY, FIFTH EDITION, BARNES AND NOBLE, P - 138, 1959)

ARRANGEMENT OF PARTS OF THE EYE PARTS CONFIGURATIONAL ASPECT DRAWING NO.4-111-01-1

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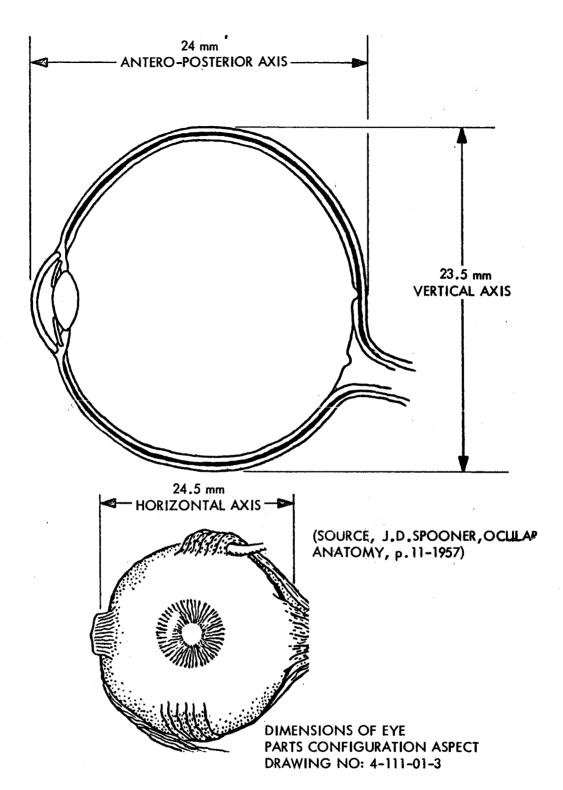
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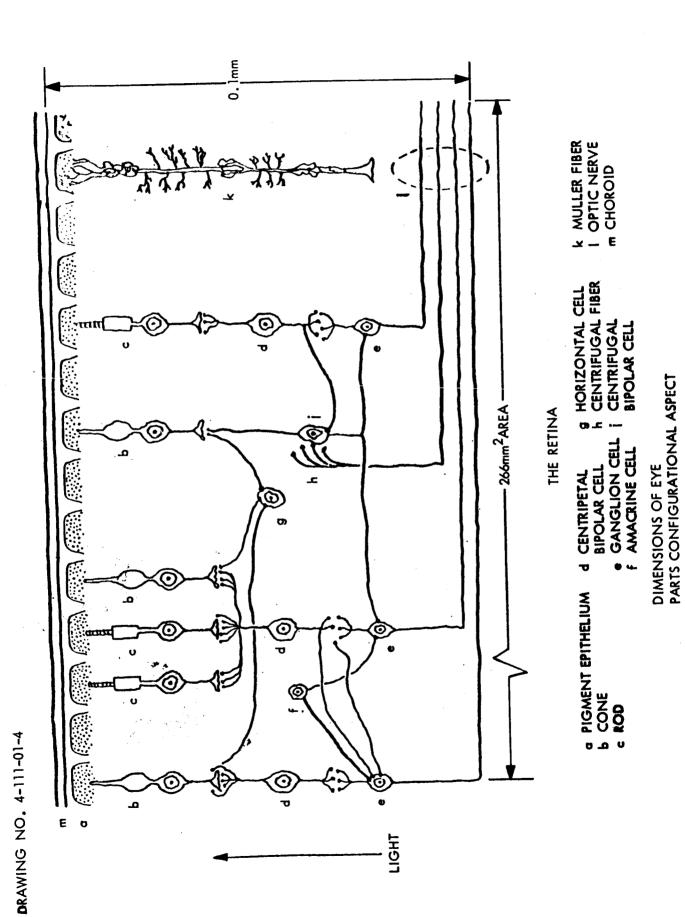
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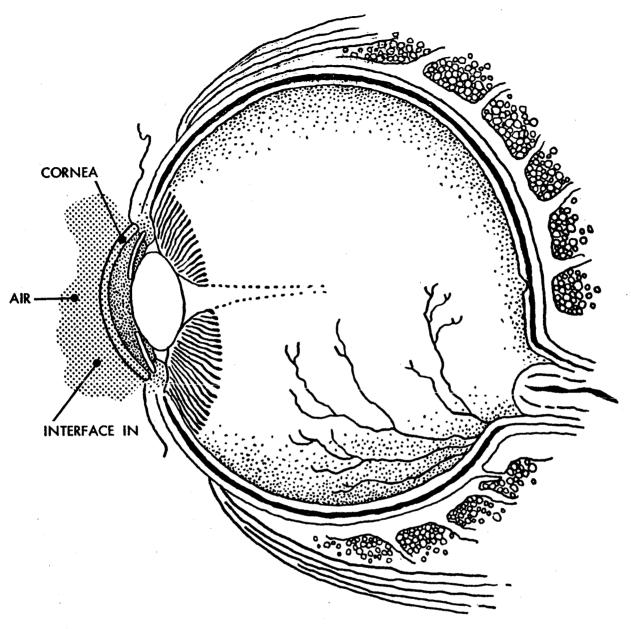
ARRANGEMENT OF PARTS OF EYE PARTS CONFIGURATIONAL ASPECT DRAWING NO. 4-1111-01-2



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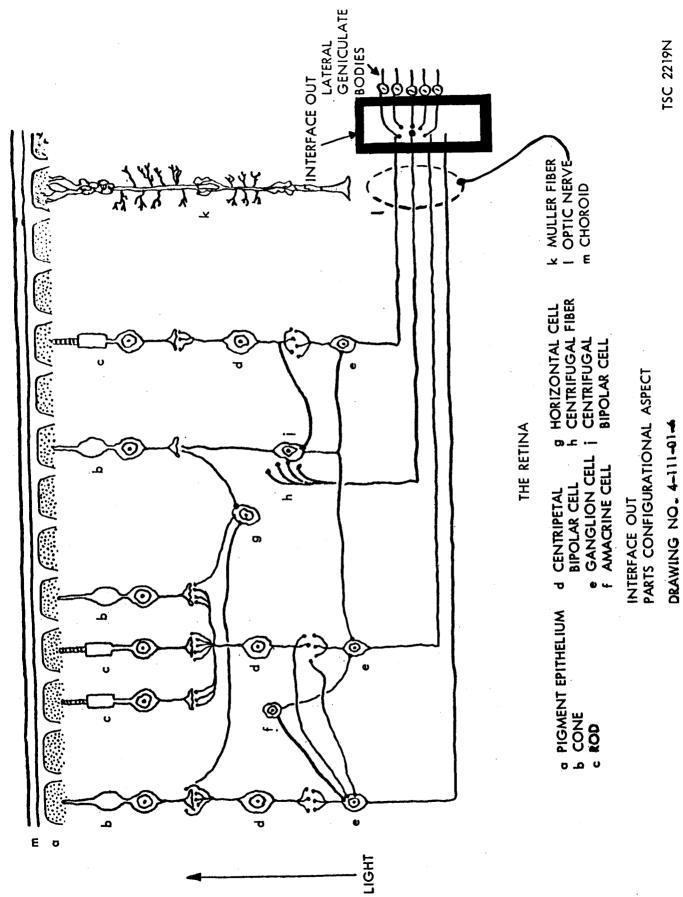
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(SOURCE, ATLAS OF HUMAN ANATOMY, FIFTH EDITION, BARNES AND NOBLE, P. 138-1959)

INTERFACE IN PARTS CONFIGURATIONAL ASPECT DRAWING NO.4-111-01-5

TSC2218K



		≥	MATERIAL INFORMATION	INFORM	AATION
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MATERIALS (next level)	EXISTENCE	AVAILABILITY	PRODUCIBILITY	RELATIVE COST	REMARKS:
TYPE:				,	
cornea					
aqueous humor					
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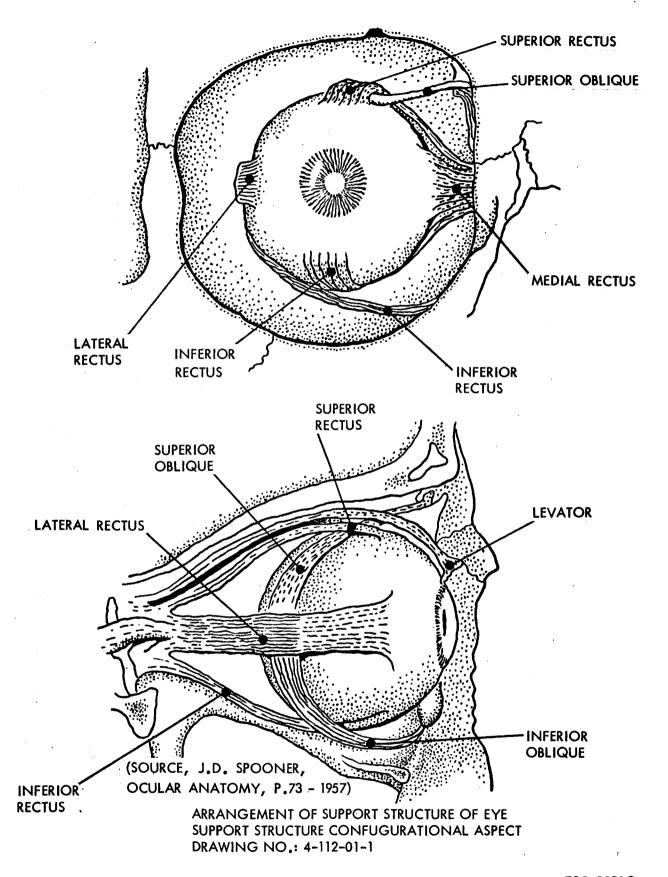
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This file contains drawings of the support structure of the eye. On the Configuration Information sheet, two drawings are called out. The first, Drawing 4-112-01-1, is an anatomical illustration that shows the six muscles that move the eyeball as well as the levator muscle that controls the eyelid. The second drawing, No. 4-112-01-2, indicates the direction in which the muscles can rotate the eyeball.

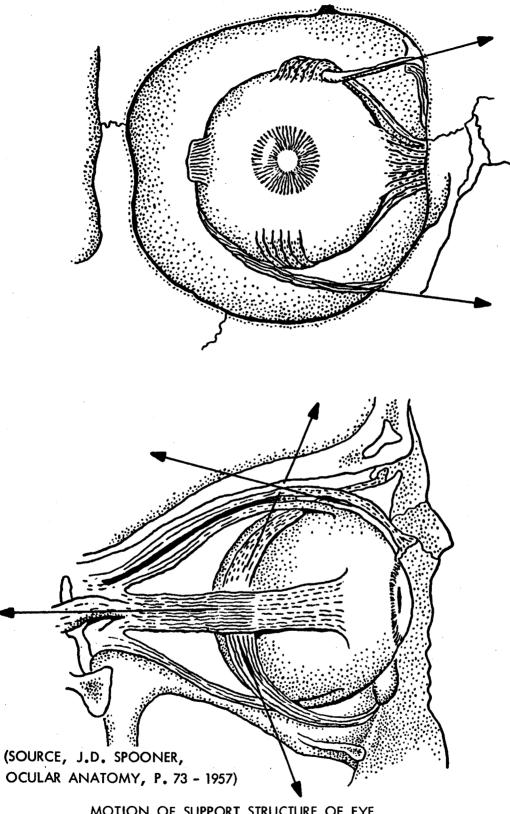
The seven muscles of the support structure are listed on Material Information sheet.

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FILE NO:	ELEMENT:	ELEMENT: Man, Input, Sensory,		Visual					
DRAWINGS  CONFIGURATION  ASPECT:	ARRANGEMENT OF PARTS	CONNECTION OF PARTS	DIMENSIONS	SHAPE	MOTION	DEGREES OF FREEDOM	ENVIRONMENT INTERFACE IN	ENVIRONMENT INTERFACE OUT	CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED
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MOTION OF SUPPORT STRUCTURE OF EYE SUPPORT STRUCTURE CONFIGURATIONAL ASPECT DRAWING NO. 4-112-01-2

TSC 2220B

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MATERIAL INFORMATION	Visual	REMARKS: cost	),																	-	
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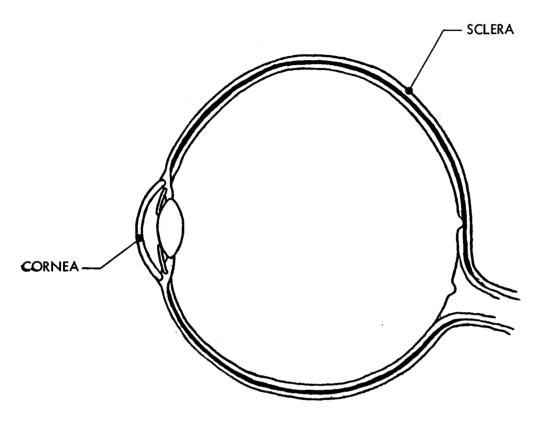
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File 4-113-01 covers the configurational aspect called container. The Configuration Information sheet lists drawings of the container of the eye. As is shown on Drawing 4-113-01-1, the cornea and sclera compose the container. The dimensions of the container are given on Drawing 4-113-01-2. These dimensions indicate that the container (eyeball) is nearly round and almost fills a one-inch sphere.

Only the cornea and sclera are listed on the Material Information sheet.

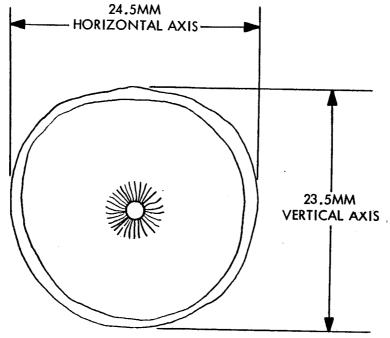
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FILE NO: 4-113-01	ELEMENT:	Man, In	Input, Sensory,	ry, Visual					
DRAWINGS CONFIGURATION ASPECT:	ARRANGEMENT OF PARTS	CONNECTION OF PARTS	DIMENSIONS	SHAPE	MOTION	DEGREES OF FREEDOM	ENVIRONMENT INTERFACE IN	ENVIRONMENT INTERFACE OUT	CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED
Container	Drawing	Drawing No.	Drawing No.	Drawing No.					
	4-113-01-1	4-1	4	4-1131-2					
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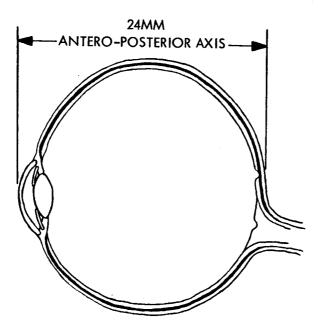


(FROM: ATLAS OF HUMAN ANATOMY, FIFTH EDITION, BARNES AND NOBLE, 1959, P. 138)

ARRANGEMENT OF PARTS OF CONTAINER CONTAINER CONFIGURATIONAL ASPECT DRAWING NO.: 4-113-01-1



FRONT VIEW OF EYE



SIDE VIEW OF EYE

(Source, J.D. Spooner, Ocular Anatomy, p. 11-1957)

DIMENSIONS OF CONTAINER OF EYE CONTAINER CONFIGURATIONAL ASPECT

DRAWING NO. 4-113-01-2

**TSC 2220A** 

		~	MATERIAL INFORMATION	INFORA	MATION
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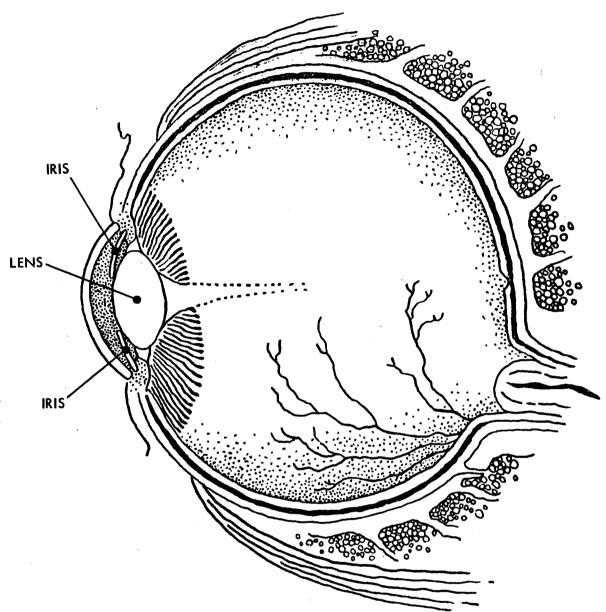
File No.: 4-114-01

Drawings concerned with the internal dynamics of the eye are included in this file. The Configuration Information sheet lists two drawings. On the first drawing, No. 4-114-01-1, the iris and lens are pointed out because they have motions that take place within the container of the eye. The maximum and minimum limits of these motions are shown on Drawing 4-114-01-2. It may be noted that both the curvature and the diameter of the lens change when accommodation takes place. Accommodation is the change in the eye to bring objects at various distances into focus. The variation in the diameter of the iris to control the amount of light that strikes the retina may also be seen on this drawing.

The iris and lens are listed on the Material Information Sheet as the components that have internal dynamics.

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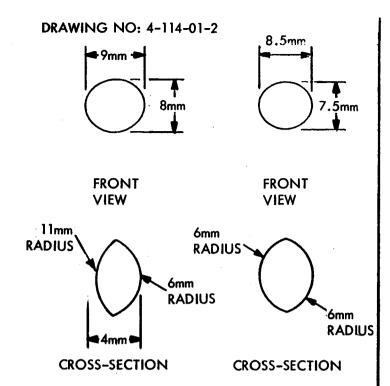
			CONFIG	URATION	CONFIGURATION INFORMATION	MATION			
FILE NO: 4-114-01	ELEMENT: Man,		Input, Sensory, Visual	Visual					
DRAWINGS CONFIGURATION ASPECT:	ARRANGEMENT OF PARTS	CONNECTION OF PARTS	DIMENSIONS	SHAPE	MOTION	DEGREES OF FREEDOM	ENVIRONMENT INTERFACE IN	ENVIRONMENT INTERFACE OUT	CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED
Internal	Drawing No.	Drawing No:		Drawing No:	Drawing No:				
Lynamics	4-114-01-1	4-114-01-1		4-114-01-1	4-114-01-2				
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(SOURCE, ATLAS OF HUMAN BODY, FIFTH EDITION, BARNES AND NOBLE, P:138 - 1959)

ARRANGEMENT OF PARTS
INTERNAL DYNAMICS CONFIGURATIONAL ASPECT
DRAWING NO. 4-114-01-1

TSC2218J



IRIS IRIS

**MAXIMUM** 

**DILATION** 

LENS
UNACCOMMODATED FULL
ACCOMMODATION
(SOURCE, J.D. SPOONER, OCULAR ANATOMY,
p. 11-1957

(SOURCE, F.H. ADLER, PHYSIOLOGY OF THE EYE, p. 170-1959)

**MAXIMUM** 

CONSTRICTION

MOTION
PARTS CONFIGURATIONAL ASPECT

DRAWING NO: 4-114-01-2 TSC 2544

		*	MATERIAL INFORMATION	INFOR	MATION
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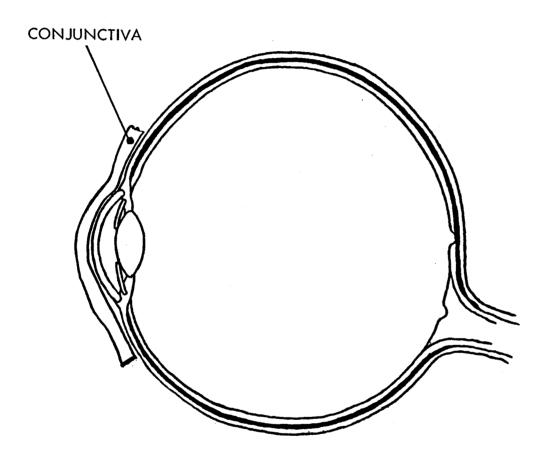
File 4-115-01 covers the configuration aspect called external dynamics. The Configuration Information sheet calls out Drawing 4-115-01-1. This drawing indicates that the conjuctive has dynamics that are external to the container of the eye. The conjuctive is controlled by the levator muscle (Drawing 4-112-01-1). On Drawing 4-115-01-1, the motion of the conjuctive is shown.

On the Material Information sheet, the conjuctiva is listed.

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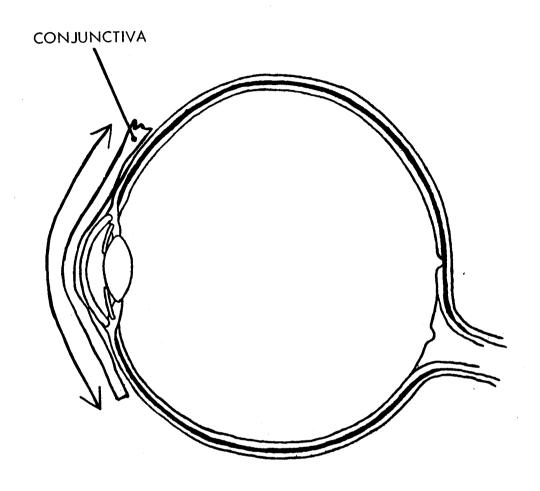
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(SOURCE, ATLAS OF HUMAN BODY, FIFTH EDITION, BARNES AND NOBLE, P. 138 - 1959)

ARRANGEMENT OF PARTS
TRANSVERSE SECTION OF EYE
EXTERNAL DYNAMICS CONFIGURATIONAL ASPECT
DRAWING NO.4-115-01-1

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MOTION
TRANSVERSE SECTION OF EYE
EXTERNAL DYNAMICS CONFIGURATIONAL ASPECT
DRAWING NO. 4-115-01-2

File No: 4-116-01

The Material Information sheet contains a list of the major components of the eye. No data is entered in the columns labeled Existence, Availability, Producibility, and Relative Cost, since all of the components are known to occur in every human eye. These columns are needed when designing a component.

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COMPONENT LEVEL EXAMINATION OF THE OPERATION OF THE HUMAN EYE

The human eye is composed of many types of organic cells. Each of these cells are components of the visual sensor. A complete component level analysis would require that the Methodological procedure followed at the Subsystem Level be repeated for every type of cell within the eye.

As Table I indicates, there are at least 66 types of cellular structures in the eye. The table shows that a number of components may be grouped together to form parts of the eye. For example, there are 13 components that form the cornea. To investigate the components of the eye requires repeated applications of the Methodology.

A comprehensive study of most of these components is not warrented at this time. Knowledge of the processes conducted within a few components could however give insight into a considerable segment of the visual mechanism. This may be illustrated by examining the basic visual functions of a number of parts of the eye. Examples of visual functions are indicated in the following list: cornea-frequency and intensity filtering and refraction of light; lens - refraction of light and iris - control of amount of light entering eye. There are many other parts of the eye that have visual functions that are well known, but there are components that perform a large and complex portion of the visual process and are not presently well understood. These are the components that deserve study.

	Cornea		Retina
1.	Basal cells	35.	Pigment epithelium
2.	Polyhedral cells	36.	Rod cells
3.	Epithelial cells	37.	Cone cells
4.	Endothelial cells	38.	Centripetal cells
5.	Corneal corpuscles (fixed cells)	39.	Ganglion cells
6.	Leucocytes (wandering cells)	40.	Horizontal cells
7.	Lymph cells	41.	Amacrine cells
8.	Nerve cells (neurons)	42.	Centrifugal cells
9.	Vascular loops (blood vessels)	43.	Centrifugal fibers
10.	Bowman's membrane	44.	Muller fibers
11.	Descemet's membrane		
12.	Elastic fibers	45.	Optic Nerve
13.	Inelastic fibers (collagenous fibers)		
	·	46.	Aqueous Humor
	Iris		
14.	Epithelial cells	47.	Vitreous Body
15.	Endothelial cells		
16.	Pigment cells		Sclera
17.	Vascular loops	48.	Inelastic fibers
18.	Inelastic fibers	40.	
19.	Elastic fibers	49.	(collagenous fibers) Elastic fibers
20.	Dilator muscle	50.	Fixed cells
21.	Sphincter muscle	50. 51.	
<b>.</b>	ophineter muscle	52.	Pigment cells Nerve cells
	Lens	52. 53.	· · · ·
	<del></del>	55.	Vascular loops
22.	Epithelial cells	54.	Conjunctive
23.	Lens fibers	55.	Conjunctiva Levator muscle
24.	Cement substance	<i>JJ.</i>	Levator muscle
25.	Suspensory fibers		Muscles
	Ciliary Muscle		
	26. Muscle fibers	56.	Superior rectus
	27. Elastic tissue	57.	Inferior rectus
	28. Nerve cells	58.	Lateral rectus
	-0. 110170 00110	59.	Medial rectus
	Ciliary Body	60.	Superior oblique
	Ciliary Body	61.	Inferior oblique
29.	Pigment cells		
30.	Epithelial cells		Choroid
31.	Hyaloid cells	62.	Vascular loops
32.	Processes	63.	Pigment cells
33.	Vascular loops	64.	Hyaloid cells
34.	Connective tissue	65.	Elastic fibers
		66.	Inelastic fibers
			(collagenous fibers)
			,

## COMPONENTS OF THE HUMAN EYE

Table I

### OUTLINE OF PHOTORECEPTOR PROCESSES

Two components that are involved in the major energy conversion that occurs within the eye are the rod cells and the cone cells (the photoreceptors). There is considerable similarity in the operation of these cells since both absorb visual radiation and convert it into neural pulses that excite the centripetal bipolar cells (primary neurons of the eye). An examination of one of these components will yield a considerable amount of information that will apply to the other. To date much more effort has been expended in studying the rod cells, though it has been found that the chemical cycle traced by both of the photoreceptors is closely related.

Quite naturally subjects other than humans are required to supply rod cells for study. It has been learned that the photochemical substance rhodopsin found in the rods of man is also present in the retinae of mammals, birds, amphibians, and sea vertebrates. The retinae of cattle, frogs, and rats have been used as sources of rhodopsin. Cone cells contain the visual pigment iodopsin that is experimentally secured from chicken retinae. I

#### Rhodopsin

The photochemical rhodopsin sometimes referred to as visual purple, is concentrated at the rod surface. Visual purple is a complex substance that has not been analyzed completely; however, it can be said that this organic compound contains chromophores and a protein (scotopsin). The number of chromophores per protein molecule is not known, and estimates range from one to ten.  $^2$  A chromophore is that portion of a photochemical that selectively absorbs part of the visible spectrum.  $^3$  In rhodopsin the chromophore is called retinene, which has the formula  $C_{19}H_{27}CHO$ . Iodopsin contains retinene, and a protein called photopsin.

Molecules of retinene l and protein allow their free electrons to mutually interact to construct single covalent bonds between each adjacent atom as well as to build π-orbitals. These orbitals are formed by the excess electrons that are not part of the covalent bonds and extend over the whole length of the conjugated chain. In the unexcited state the electrons occupy orbitals of the lowest energy; when absorption of light quanta takes place, the electrons enter orbitals of higher energy. 4

"The oscillating electric vector of light causes the  $\pi$ -electrons to congregate backwards and forwards along the conjugated chain, first at one end and then at the other. When the light is of the proper frequency to correspond with the rhythm of these oscillations, it is strongly absorbed (the fundamental band in the visible)."  $^5$ 

The fundamental band defines the wavelength of the absorption maximum (symbolized as  $\lambda$  max.). This parameter is used because the only known way of characterizing a visual pigment is to measure its light absorbing properties.

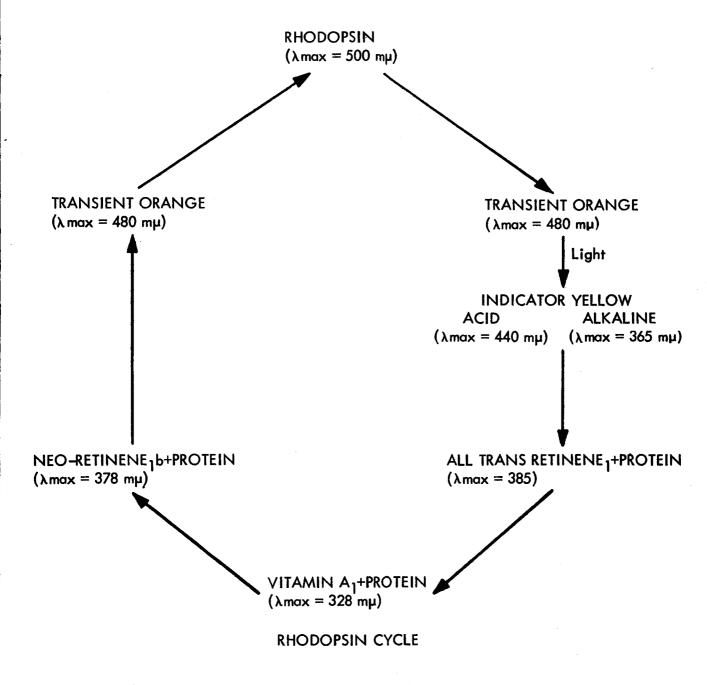
When the chormophore of rhodopsin absorbs a quantum of energy, the rise in electronic levels causes a change in the configuration of the chromophore so that it releases the protein and dissociation takes place. This causes the electric tension between chromophore and protein to disappear.

## Rhodopsin Cycle

Perhaps the best method of explaining the chemical changes that rhodopsin undergoes is to present the complete cycle that this photochemical undergoes and then give the necessary details. Figure I is a diagram of the rhodopsin cycle.

Even before exposure to light, rhodopsin can form transient orange. At room temperature, transient orange has a very short life, and in the presence of light is converted to indicator yellow, which is the first stable decomposition product of rhodopsin. In an acid (pH 5.2) solution, the indicator is bright yellow, while in a base (pH=9-9.5), the chemical is nearly colorless.

Indicator yellow is composed of the chromophore retinene and a protein. The configuration of indicator yellow is shown in Figure II. If thermal energy is given to indicator yellow, there is decomposition into all trans retinene and protein. All trans retinene is the isomer of the chromophore retinene that involves the least strain. Retinene occurs in two types of isomers, cis and trans. The basic difference between cis and trans isomers is shown in Figure III.



(ADAPTED FROM DARTNALL, THE VISUAL PIGMENTS, 1957, PAGE 54 AND 152)

Figure I

ALKALINE INDICATOR YELLOW  $(\lambda max = 365 m\mu)$ 

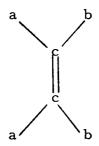
ACID INDICATOR YELLOW  $(\lambda max = 440 m\mu)$ 

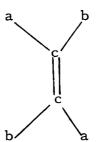
ALKALINE AND ACID FORMS OF INDICATOR YELLOW (DARTNALL, THE VISUAL PIGMENTS, 1957, PAGE 109)

Figure II

cis isomer

trans isomer





Isomers of Chromophores
(Dartnall, The Visual Pirgments, 1957, Page 127)
Figure III

All trans-retinene  $_1$  has the configuration shown in Figure IV. The cis isomer will be encountered in the discussion of the resynthesis of rhodopsin. By thermal and enzymic action, all trans retinene  $_1$  is converted to vitamin  $A_1$ . The protein molecule is still present and is not bonded to the vitamin  $A_1$ . The shorthand structural formula for vitamin  $A_1$  is shown in Figure V.

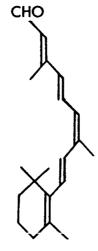
Vitamin  $A_1$  is the final chemical formed in the decomposition phase of rhodopsin. This phase of the rhodopsin cycle takes place when light impinges on the photoreceptors. An environment of darkness is required to allow the regeneration of visual purple to take place.

It has been found that the photoreceptors must be in contact with the pigment epithelium to allow rhodopsin to regain its color in darkness, but this contact is not necessary during the bleaching of the photochemical. <sup>8</sup> This observation brings up the question of how the pigment epithelium influences the regeneration process.

Microscopic examination has disclosed that the pigment epithelium has processes that project like bristles from a brush and lie in the spaces between the photo-receptors. The processes contain pigment in granular and spindle form. During regeneration the outer segment of the cone photo-receptors has been observed to lie in contact with the processes of the epithelium and to directly absorb pigment granules. These granules very likely take part in the photochemical cycle that is carried out by the cones. Though not yet observed for the rods, a similar exchange of pigment granules probably is carried out by this second type of receptor. To date the importance of this phenomenon in the photochemical cycle has not been explained.

Laboratory tests indicate that regeneration can be started by introducing alcohol dehydrogenase that acts as a catalyst in the oxidation of vitamin A<sub>1</sub> to neo-retinene<sub>1</sub> b, which is a cis isomer of retinene<sub>1</sub>.

Figure VI illustrates the configuration of neo-retinene<sub>1</sub> b. A spontaneous energy releasing reaction takes place in which neo-retinene<sub>1</sub> b and protein recombine to form the original photochemical. Thus, the rhodopsin cycle is completed.



THREE CIS NEO-RETINENE<sub>1</sub> b  $C_{19}H_{27} \cdot CHO$   $(\lambda max = 378 m\mu)$ 

Figure VI

## References for Outline of Photoreceptor Processes

- 1. Dartnall, H. J. A., The Visual Pigments, John Wiley and Sons, New York, 1957, p. 37.
- 2. Hartridge, Hamilton, Recent Advances in the Physiology of Vision,
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- Adler, Francis Feed, Physiology of the Eye, Third Edition,
   V. Mosby Company, St. Louis, 1959, p. 506.
- 4. Dartnall, p. 101.
- 5. Dartnall, p. 133.
- 6. Dartnall, p. 123.
- 7. Dartnall, p. 52.
- 8. Dartnall, p. 26
- 9. Last, R. J., Anatomy of the Eye and Orbit, W. B. Saunders Company, Philadelphia and London, 1961, p. 94.
- 10. Last, p. 97.
- 11. Dartnall, 136.

# COMPONENT LEVEL APPLICATION OF THE MAN-MACHINE SYSTEMS METHODOLOGY

The Component Level application of the Methodology to the photoreceptor cells could be delineated at this point utilizing the physiological background that has been presented. However, even before beginning this task it may be recognized that there are essential areas that have not been investigated.

One of the most prominent problems that has been left unanswered concerns frequency detection within the rods. This brings up the general question of the mechanism of color vision. Does the photo-receptor cell carry out the major portion of the color vision process? Is an understanding of the chemicals within the photo-receptors the key to an explanation of color vision?

The answers to these questions require research into the fundamentals of color vision. To date, physiological research has not examined the basic mechanisms of color vision, but has promulgated the so-called "three color theory". This theory assumes that there are three types of photo-receptors in the eye that are each sensitive to a different portion of the visible spectrum. When the three work in combination, enough information is provided to the brain to convey the shade of any color.

As a starting point in answering some of these questions, the phenomenon discovered by Edwin H. Land of the Poloroid Land Camera Corporation will be studied. Land demonstrated that color could be produced from two black and white positive transparencies, one that was projected through a red filter and the other with white light. This was a demonstration that two colors can be used to produce (at least subjectively) the entire visible spectrum. This problem will be investigated by Teledyne, and some results will be given in the final report under this contract.

#### CONCLUSIONS

Research into the operation of the visual sensor has developed the initial human analog of the eye. The human analog has been constructed by filling out a group of tabular forms for each Methodological aspect.

This method of developing the human analog has proved to have a number of desirable features. Tabular format has allowed a non-linear system such as the eye to be described. Lack of applicable differential equations that could be used to construct a human analog has not been an obstacle. Every piece of data that was produced was found to have a specific place on the Information Sheets.

Comparing the human analog that this report has produced to previous efforts at describing the operation of the eye, the merits of the present approach may be realized. Prior physiological investigation approached the eye by dissecting it into arbitrary anatomical parts and then analyzing the function of each of these pieces. No consideration was given to how the function of a small part contributed to the operation of the entire eye. An example of this concern with detail is the concentration on each of the types of cells within the cornea while ignoring their contribution to the visual process. Table I in the section "Component Level Examination of the Operation of the Human Eye" lists thirteen cornea components that are separately analyzed in ocular anatomy. As this table indicates, the eye has been divided into dozens of cellular components by the anatomists, and as a result, investigators that have studied functional relationships of a few of these parts have not produced basic insights into the visual process.

In the research that has been conducted, attention was directed toward keeping extraneous details out while striving to utilize information that would illuminate the visual process. The entire Subsystem investigation was carried out in a framework that oriented data toward a clearer understanding of the human eye. Each intersection of the Subsystem Matrix considered provided a description of another facet of the operation of the entire eye. For all of the intersections discussed, information was directed toward explaining the overall subsystem and not in developing relationships between the various facets. Anatomical data has been primarily grouped under the heading Configuration Information and has thus been separated in each file.

One of the guiding principles that was utilized by the Function
Influencing Factor was to trace the information signal. Each of the aspects
considered under Function presented a description of this signal during a
specific phase. A basic question was answered when a description of how
the eye detects the information signal was given. As this signal was traced,
a clear idea of the form of the information envelope was obtained. For
example, the information signal was in the form of transverse ion flow
within the neurons of the retina. The composition of the signal as well
as the energy conversions undergone were described. Concentration on
tracing the information signal has produced a human analog that has described the basic processes of the eye. The Man-Machine Methodology has
suggested that a guide to all scientific investigation concerned with probing
functional operation is to trace the flow of the information signal.

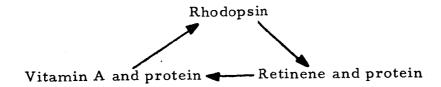
During the collection of data on the photochemical reactions that take place within the rods and cones (photoreceptors), it was found that the literature described various chemicals. Many of these chemicals have not been found in the eye, but were discussed because they can react to form

compounds that have been located in the photoreceptors. In order to produce some desired reactions, these "selected" chemicals were heated to temperatures considerably above that found in the rods for periods of many minutes. Frequently these reactions were repeated, each time at a different pH. Here again the laboratory experimentation was performed without consideration of the pH changes within the photoreceptors.

There is a lesson to be learned from these observations. When studying the photoreceptors, the primary concern should be with the chemicals within these cells. The environment of the chemicals should be kept in mind while relating all experimental parameters to the known conditions in the photoreceptors.

Perhaps some of the misdirection discussed above is responsible for the lack of insight into the visual pigment (rhodopsin) contained within the rods. As was mentioned in the section "Outline of the Photoreceptor Processes", the ratio of the number of molecules of chromophore to that of protein is not accurately known, and these are the only two constituents of rhodopsin.

The present day literature describing the physiology of the eye contains many references to a rhodopsin cycle (shown below) that was developed prior to 1940.



This has become the classic cycle. But it is incorrect as indicated by the explanations of the breakdown and resynthesis of rhodopsin that are given in these same books. A new cycle was developed, while constructing the scheme shown in Table I of the section "Outline of Photoreceptor Processes." A number of previously unrelated facts were used to correct and update the classic rhodopsin cycle.

If scientific researchers would utilize the Man-Machine Methodology, data that is related would be brought together. The Methodological framework represents an excellent structure to store all pertinent information. Prior to applying the Methodology, it will be necessary to gain a general familiarity with the subject. This has been illustrated in the present report by the inclusion of the sections that give physiological outlines of the operation of the eye and the photoreceptor processes.

The Methodological approach has led to the disclosure of areas in which basic research is needed. In the investigation of the Functional Aspect of Detect (File No. 4-79-01), it was found that the literature did not contain an explanation for this function. Thus one area in which research would be profitable is to study how a structure, such as the eye, detects visible radiation. This research could produce results that would apply to the detection of the entire electromagnetic spectrum.

In order to explain how the eye detected and absorbed visible radiation, a hypothesis was proposed in File No. 4-79-01. This hypothesis was based on the phenomenon of resonance. It was assumed that there were resonant structures within the eye that responded to the frequencies of visible radiation. Physiological evidence suggested that these structures were located in the rods and cones. When electromagnetic radiation in the visible spectrum impinged upon the photoreceptors, the latent ability of these structures was utilized and resonance occurred.

The initiation of resonance was considered to constitute the detection function while the actual dislocation of particles was described under the aspect of quantize (File No. 4-80-01). Quantization was hypothesized to commence after the completion of detection. When energy absorption by the resonating structures reached a specific level, electrons were freed from their bonds and moved from the photoreceptor surface into the receptor proper. The energy of the electrons was in proportion to the activity of the visible radiation that was absorbed by the resonant structure.

With the hypothesis above in mind, the investigation of the photoreceptors at the Component Level was begun. A description of the previously hypothesized resonant structures within the photoreceptors was found. These structures are called Torbitals and are constructed by the excess electrons that remain after covalent bonds have been formed between the two molecules that compose rhodopsin.

The reported existence of these structures helps to substantiate the resonance hypothesis. Another confirming factor is an explanation of how the resonance process takes place by H. J. A. Dartnall in his book The Visual Pigments, page 133. Dartnall explains that the oscillation of impinging radiation causes the structures with the latent ability to resonate to move back and forth along the conjugated chain, congregating alternately at each end. Only light that is of a frequency that can resonate with the rhythmically oscillating  $\pi$ -orbitals will be strongly absorbed.

Development of the resonance hypothesis, that has been described above, has applications that are much wider than only explaining how the photoreceptors detect visible radiation. The entire electromagnetic frequency range is encompassed by this hypothesis because all energies in this spectrum are absorbed in a similar manner. Basic research that would establish or modify this hypothesis could produce a new fundamental physical law.

Investigation of the functional aspect called Qualify (File No. 4-81-01) led to the disclosure of another area in which research is needed. When the question of how the eye determines what frequencies are impinging on the photoreceptors was encountered, it was found that an understanding of color vision was required. Examination of color vision properly should take place at the Component Level and thus the Qualification aspect did not discuss this topic.

Teledyne Systems Corporation will investigate color vision and attempt to assess if three photopigments are actually required. In an article published in "Scientific American," May 1959, Edwin H. Land described how two colors could be used to produce the sensation of the full spectrum. Perhaps the eye in conjunction with the brain can produce all of the colors using only two photochemicals in the retina. This study will try to find answers to a number of questions raised by Land's article as well as attempting to suggest a valid approach to a three color theory of vision.

The human analog was written in the terminology of the Man-Machine Methodology and thus can be directly applied to the design of machine extenders. Useful machine extenders can be derived from the human analog in a much more straightforward fashion than from a physiological explanation of the operation of the eye. Since the human analog has been organized according to the influencing factors of the Methodology, design information may be easily located under the appropriate factor of environment, function, configuration or material.

Deriving machine extenders from a human analog has the advantage that there is no technical language barrier to hamper the retrieval of information from the Methodological forms. Terminology used in developing the human analog is common to all fields of science and thus a physiologist, who may gather information for the Methodological forms, can easily be understood by an engineer, who may be designing a visual extender. After the designer of machine extenders has become familiar with the applicable data contained in the human analog, he can directly apply this information in the implementation of the device.

By using the human analog of the eye, design criteria for machine extenders may be developed that are considerably more sophisticated than presently available. Today there are machine extenders that are based on the most obvious principles of operation of the visual sensor. Enormous optical telescopes have been constructed that simply act as enlarged retinal surfaces in gathering light. For viewing small objects, microscopes have been constructed with components that magnify the image as is the function of the crystalline lens of the eye.

A number of the statements made in the preceeding paragraphs may be clarified by tracing through a design example. Consider the design of a device that would enable the eye to operate in a environment of much lower light intensity than the unaided visual sensor. First information under the functional aspect of qualify should be reviewed. Here a discussion of how the eye attenuates the intensity as a function of frequency will be found.

At the Subsystem Level the aspect of qualify (File No. 4-80-01) dealt with the entire eye and did not discuss how the individual components attenuated the intensity. Each of the components that filter light should be individually investigated in order to establish how much the entering light is attenuated as

it passes through each part of the eye. Such a study will reveal those frequencies that would be most desirable to utilize for optimum performance of the rods under low light level conditions.

Now a machine extender could be designed that modifies the light before it enters the eye. The device would transmit the information signal to the visual sensor on the selected frequencies. It is true that such a device would not present a normal frequency spectrum to the eye, but this is not grounds to conclude that the colors transmitted by the device and interpreted by the brain would be different from those reflected directly from the object. The study that Teledyne Systems Corporation is currently engaged in may enable such a device to be designed so that the apparent colors were not altered. This study could establish some new concepts in the understanding of color vision.

After an understanding of the human analog of the eye has been accomplished, machines can be designed that work on the same principles as those used by the visual sensor. Such machines would have advantages over presently available devices. These new machines could operate at low frequencies after detecting the information signal as is the case in the eye. Rather accurate spacial relationships could be transmitted with building blocks that are similar to the neurons in the retina.

Research into the human analog of the eye has proved fruitful in many ways. As the first detailed application of the Man-Machine Methodology at the Subsystem Level, this report serves as a model for future reseach. The human analog has located some areas that could profit greatly by physiological investigation. It was found that studies of the eye could produce more insight to the visual process by following the format of the human analog. Many scientific researchers in diverse fields of study can profit by a close examinantion of the human analog of the eye.

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APPENDIX A

The Methodology is based on a hierarchy of levels that succeedingly become more detailed. In order to completely analyze a problem, the Methodology must be traced to the most basic level, but it may not be necessary to begin at the most general level, i.e., investigation of the visual sensor began on the subsystem level. For convenience the levels have been given decimal numbers. Table A shows the numbering of the levels beginning with the most general.

Number	<u>Le vel</u>
1	Mission
2	System Complex
3	System
4	Subsystems
5	Component
6	Chemical
7	Physics

Number of Levels

Table A

These levels are divided into elements which are listed by columns on all Methodology matrix charts, Tables B through F. Each element has a decimal identification number. Examples of this numbering code may be seen on the matrix charts, Tables E and F.

The charts show the breakdown of each level into the following four influencing factors: environment, function, configuration, and material. Each influencing factor is broken into various aspects that are listed as separate rows on the charts. Again the aspects are decimally numbered to facilitate identification of a row or an intersection.

For ease of reference, any intersection on one of the matrix charts can be identified by a coded number. Every coded number has three parts, each separated by means

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SYSTEM COMPLEX MATRIX CHART

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SYSTEMS MATRIX CHART

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SUBSYSTEM MATRIX CHART FUNCTION, CONFIGURATION, MATERIAL

Table F.

of dashes. First the level is given as shown on Table A; then, the row is called out, and finally the column is identified. An example of a coded number is 4-22-13. Four calls out the subsystem level matrix chart while 22 is the aspect called force, pressure and 13 is the man, output, musculo-skeletal column.

There is a form for each of the influencing factors that is called an information sheet. These forms are used to describe an influencing factor. In order to complete the description, supplemental information sheets may have to be filled out under the heading of an influencing factor. Thus, the same form may be used for more than one factor and the information contained will be different. Table G gives the organization and methodology order of the information sheets for all levels.

Primary Influencing Factors	Supplementary Sheets	Information Content
Environment		Environment of entire object
	Function	Function of entire object in a given environment
	Configuration	Configuration of materials that are affected by environment
	Materials	Materials of object that are affected by the environment
Function .		Function examined by aspect for a given environment
	Configuration	Configuration of materials that are concerned with performing the function
	Materials	Materials that are concerned with performing the function
Configuration		Configuration of materials that compose of the entire object
	Materials	Materials of entire object grouped according to configuration break-down
Materials		Materials that compose the entire object grouped by materials breakdown

Organization of Information Sheets

Table G

# Information Sheets

Application of the Man-Machine Systems Methodology entails the filling out of the information sheets that are listed on Table G. This table indicates each of the four influencing factors and their associated supplementory sheets. The ordering of the forms shown on Table G will be followed in assembling the information sheets. A general statement of the content of each sheet is given on the following pages.

# Environment Information Sheet

On the environment information sheet, all the parameters required to describe the environment are listed, and data pertaining to each are given.

On the following page is a blank environment information sheet that may be referred to in locating the terms that are defined below.

Term	Definition
Element	Column heading
Parameter	Manifestation of energy of the object
Quantity	Amount/some selected unit volume
Rate of Normal Incidence	Number of exposures/unit time
Rate of Change	Rate of change over a selected time interval
Amt	Amount
Dur	Duration

Definition of Terms on Environment Information Sheet

Table H

THE NO :    ELEMENT:   COLUMN	FILE NO :	ELEMEN													
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PARAMETER	TWINDOWN	AMT	DUR	AMT	DUR	AMT	DUR	AMT	TIME	AMT	DUR	AMT	DUR	AMT	DUR
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### Function Information Sheet

The Function Information sheet has many columns to describe an object and how it is modified. This description has a number of limitations. The first stems from the division into input, distribution and control and output. Each of the functional aspects falls within one of these divisions. The functional aspects at the subsystem level are listed on Table F. They are the rows numbered from 78 - 109. The eye, which is a subsystem, is also divided into input, distribution and control output. When discussing a specific functional aspect, only that portion of the eye that is within the same division (input, distribution and control and output) may be included. As an example, under the functional aspect of transmit decoded signal (4-95-01, Table F), only the signal that is leaving the distribution and control portion of the eye can be discussed.

A second limitation on the function information sheets is concerned with the level of examination. If a problem is being examined on a specific level, then information on the function sheet can only refer to details that are on the next lower level; for example, a function sheet on the subsystem level can explain phenomena with details from the component level. This means that on the subsystem level explanations cannot include statements of how specific chemicals or atoms interact.

In some cases, a hypothesis may be proposed to explain a functional aspect. For this aspect, explanations may include mention of phenomena that take place more than one level down, but these interactions may only be located within a component that is one level down. An example to illustrate this situation may be found by considering a hypothesis to be proposed on the subsystem level. The hypothesis may discuss atomic interactions, but the specific atoms may only be located within the components and not within chemicals that compose the components.

The outputs of components, regardless if they are subatomic particles, atoms or chemicals, can be discussed at any level since they are not internal to the components. This concern with the materials from specific levels that may be discussed on function information sheets stems from rules of the methodology. These rules control the organization of data and require concentration on each level as it is

encountered while putting off consideration of more detailed information. Thus, it will be found that at the higher levels, many of the columns on the function sheets will be blank because the information needed cannot be included at that level.

At every level, the entity under consideration is divided into its functional segments. These segments include the input, distribution and control and output. The physical boundaries of these segments are not critical since any details that are not encountered at one level will be met at a lower level. As an example, consider that the iris and lens are in the input portion of the eye. Both of these components accept an internal control signal that stimulates their muscles, but this functional aspect is listed in the distribution and control portion of the eye. Therefore, these components will not be discussed under accept internal control signal. When the iris and lens are investigated on the component level, the internal control signal will be described.

On the following page is a blank function information sheet that may be referred to in locating the terms that are defined below.

Term	Definition
Element	Column heading
Aspect	Row heading
Object	Totality that brings energy in
Parameter	Manifestation of energy of the object
Characteristic	Dynamics of property
Convert to	New energy form of the object
Method	Way in which unit of the environ- ment is classified
Method Sub-Detail No. 1	Way in which unit of the environ- ment is classified - next lower level
Mechanism	Dynamic means of converstion
Operation	Way in which the mechanism operates
Operation Sub-Detail No. 1	Way in which the mechanism operates - next lower level
Change when Tolerable Limits are Exceeded	Change in parameter that modifies the function

Definition of Terms on Function Information Sheet

Table K

		CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED	150.1642
`	· ·	OPERATION OPERATION SUB-DETAIL SUB-DETAIL NO. 1	
		OPERATION OPERATION OPERATION SUB-DETAIL NO. 1 NO. 2	
		OPERATION	
		MECH- ANISM	
NOI	,	METHOD SUB-DETAIL NO.2	
FUNCTION INFORMATION	,	METHOD SUB-DETAIL:	
INFC		МЕТНОБ	
CTION		CONVERT	
FUN		CHARACT- ERISTIC	
		PROPERTY	
	<u>.</u>	PARA- METER	
	ELEMENT:	овлест	
	FILE NO:	DEFINITION	ASPECT:

FUNCTION INFORMATION SHEET Table L

# Configuration Information Sheet

Under the configuration information sheet are found drawings and numerical data. Every component that is identified on a configuration drawing is of importance in relation to the influencing factor under consideration. Headings on drawings first list a descriptive title, then an anatomical description of the illustration and finally the influencing factor.

Below, the definitions for the terms on the configuration information sheet are given and on the following page a blank form will be found to aid in locating these terms.

Term	Description
Element	Column heading
Aspect	Row heading
Arrangement of Parts	Drawing
Connection of Parts	Drawing
Dimensions	On drawing
Shape	Drawing
Motion	Drawing
Degrees of freedom	Three numbers for location and three numbers to describe motion
Environment Interface In	Drawing
Environment Interface Out	Drawing
Change when Tolerable Limits are Exceeded	Point where configuration is permanently changed

Defintion of Terms on Configuration Information Sheet

Table M

FILE NO.:: ELEMENT:  DRAWINGS  ARRANGEMENT OF DIMENSIONS SHAPE WOTION OF INTERFACE  ASPECT:  PARTS				CONFIG	CONFIGURATION INFORMATION	INFOR	MATION			
ARRANGEMENT CONNECTION OF DIMENSIONS SHAPE MOTION OF INTERFACE INTERFACE IN TRANSPORT OF SHAPE OF SHAP	FILE NO:	ELEMENT:								
	DRAWINGS CONFIGURATION ASPECT:	ARRANGEMENT OF PARTS	<u> </u>	DIMENSIONS	SHAPE	MOTION	DEGREES OF FREEDOM	ENVIRONMENT INTERFACE IN	ENT	CHANGE WHEN TOLERABLE LIMITS ARE EXCEEDED
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Configuration Information Sheet, Table N

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MATERIAL INFORMATION		PRODUCIBILITY RELATIVE COST					ī									Material Information Class mais
<b>V</b>	EL EMENT:	EXISTENCE AVAILABILITY PRODUCIBILITY								•					:	Material Info
	·	MATERIALS (next level) MATERIALS	TYPE:									,				

# Material Information Sheet

The material information sheet lists the materials that compose the next lower level; for example, the materials on the subsystems level are composed of the components.

Below are defined the terms on the material information sheet. On the next page, a blank sheet is presented to aid in the location of the terms that are defined below.

Term	Description
Element	Column Heading
Type	Row Heading
Existence	Statement that the occurance of material is known or unknown
Availability	Scarcity or plentifulness of material
Producibility	Ease or difficulty of manufacture
Relative Cost	Value, worth

Defintion of Terms on Material Information Sheet

Table P